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# The Periodic System of the Elements.

| GROUPS.  | I.                                   | II.                                               | III.                                              | IV.                                               | V.                                                | VI.                                               | VII.                                 | VIII.                                                                           |
|----------|--------------------------------------|---------------------------------------------------|---------------------------------------------------|---------------------------------------------------|---------------------------------------------------|---------------------------------------------------|--------------------------------------|---------------------------------------------------------------------------------|
|          | R x <sub>7</sub><br>R <sub>2</sub> O | R x <sub>6</sub><br>R <sub>2</sub> O <sub>3</sub> | R x <sub>5</sub><br>R <sub>2</sub> O <sub>3</sub> | R H <sub>4</sub><br>R <sub>2</sub> O <sub>4</sub> | R H <sub>3</sub><br>R <sub>2</sub> O <sub>5</sub> | R H <sub>2</sub><br>R <sub>2</sub> O <sub>6</sub> | R H<br>R <sub>2</sub> O <sub>7</sub> | (R <sub>2</sub> H) } Combination<br>(R <sub>2</sub> O <sub>8</sub> ) } formula. |
| 1<br>2   | 1 H<br>Li 7,0                        | Be 9,1                                            | B 11,0                                            | C 12,0                                            | N 14,0                                            | O 16,0<br><small>[16,00]</small>                  | Fl 19,0                              |                                                                                 |
| 3<br>4   | 23,0 Na<br>K 39,0                    | 24,3 Mg<br>Ca 39,9                                | 27,0 Al<br>Sc 44,0                                | 28,0 Si<br>Ti 48,0                                | 31,0 P<br>V 51,1                                  | 32,0 S<br>Cr 52,2                                 | 35,4 Cl<br>Mn 54,9                   | Fe 55,9 Ni 58,5 Co 58,7                                                         |
| 5<br>6   | 63,1 Cu<br>Rb 85,2                   | 65,2 Zn<br>Sr 87,3                                | 69,7 Ga<br>Y 89,5                                 | 72,3 Ge<br>Zr 90,5                                | 74,8 As<br>Nb 94,0                                | 78,9 Se<br>Mo 95,6                                | 79,8 Br                              | Ru 103,5 Rh 104,1 Pd 105,6                                                      |
| 7<br>8   | 107,7 Ag<br>Cs 132,5                 | 111,8 Cd<br>Ba 136,7                              | 113,5 In<br>La 138,5                              | 117,9 Sn<br>Ce 141,1                              | 120,0 Sb<br>Di 146,0                              | 124,7 Te                                          | 126,5 I                              |                                                                                 |
| 9<br>10  |                                      |                                                   | Yb 172,7                                          |                                                   | Ta 182,3                                          | W 183,5                                           |                                      | Os 192 Ir 192,6 Pt 194,5                                                        |
| 11<br>12 | 196,5 Au                             | 199,7 Hg                                          | 203,6 Tl                                          | 206,4 Pb<br>Th 232,5                              | 207,5 Bi                                          | Ur 239,0                                          |                                      |                                                                                 |

# CHEMICAL PROBLEMS.

BY

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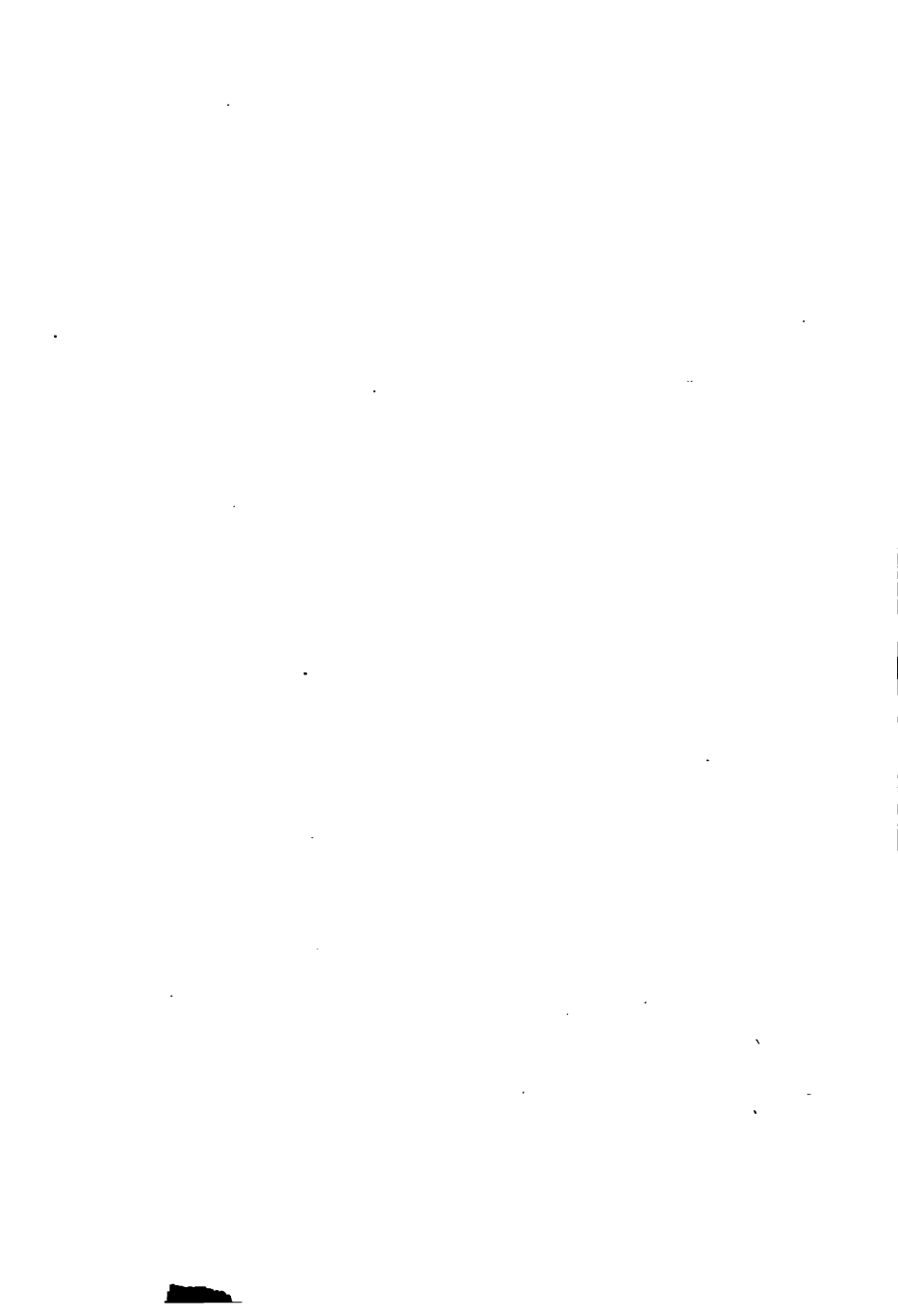
J. P. GRABFIELD AND P. S. BURNS.

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# CHEMICAL PROBLEMS.



## I.—VOLUMETRIC INTERPRETATION OF SYMBOLS.

THE symbol of the elements or compounds may represent —

*First.* An abbreviation of the name of the element or compound: as, H for hydrogen; NaCl for sodium chloride.

*Second.* A single atom or molecule of the element or molecule of the compound: as, H for one atom of hydrogen;  $H_2$  for one molecule of hydrogen; NaCl for one molecule of sodium chloride.

*Third.* A definite relative weight, called the atomic and molecular weight of the element and molecular weight of the compound: as, Cl for 35.5 parts by weight for the atom of chlorine; 71 parts by weight for the molecule of chlorine; and 58.5 parts by weight for the molecule of sodium chloride.

*Fourth.* In the case of those elements or compounds which can exist in the gaseous state, a certain volume, as will be shown in the following: —

From the law (Avogadro's Law) that *equal volumes of all gaseous substances, at same temperature and pressure, contain the same number of molecules*, it follows that the molecules of all gaseous substances occupy the same amount of space. A litre of hydrogen and a litre of chlorine have the same number of molecules. The hydrogen molecule and the chlorine molecule occupy the

same amount of space, although not necessarily of the same size (since the distance between two hydrogen molecules may not be the same as the distance between two chlorine molecules). If we assume that the hydrogen molecule occupies two volumes, then the molecule of chlorine must occupy two volumes, and so must the molecule of every other gaseous substance. In the case of hydrogen, since the molecule has two atoms,  $H_2$  stands for a molecule and for *two* volumes, while  $H$  stands for *one* volume. The same is true for all other elements having two atoms to the molecule; as, hydrogen, chlorine, bromine, iodine, oxygen, sulphur,<sup>1</sup> selenium, tellurium, nitrogen, arsenic, phosphorus, and antimony.<sup>2</sup>

When there is only *one* atom in the molecule, the symbol stands for *two* volumes. As in mercury,  $Hg$  stands for two volumes, so also with zinc and cadmium.

When *four* atoms in the molecule, the symbol stands for *one-half* a volume; as in phosphorus,  $P^2$  stands for one-half a volume, so also with arsenic and antimony.

When the element cannot be converted into a gas, we know nothing of the number of atoms to the molecule.

#### PROBLEMS.

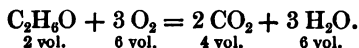
1. Write the symbol of the molecule of mercury, oxygen, arsenic, gold, nitrogen, zinc, chlorhydric acid, benzol, and ether.

*Ans.* —  $Hg$ ,  $O_2$ ,  $As_4$  or  $As_2$ , (gold not volatilized,)  $N_2$ ,  $Zn$ ,  $HCl$ ,  $C_6H_6$ ,  $C_4H_{10}O$ .

<sup>1</sup> Sulphur at  $500^\circ$  has six atoms to the molecule; above this temperature it has two atoms to the molecule.

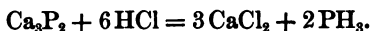
<sup>2</sup>  $P$ ,  $As$ , and  $Sb$  at  $1437^\circ$  have each a vapor density corresponding nearly to two atoms to the molecule.

2. When alcohol vapor burns, what volume of oxygen is used, and how much  $\text{CO}_2$  and  $\text{H}_2\text{O}$  gases are formed?



Since each molecule of the gas represents two volumes, for each two volumes (litres, etc.) of alcohol gas burnt, we have consumed six volumes of oxygen, and four volumes of  $\text{CO}_2$  and six volumes of  $\text{H}_2\text{O}$  gas are formed.

3. From 10 litres of chlorhydric acid gas how much  $\text{PH}_3$  gas can be formed according to the following reaction : —



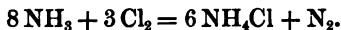
From six molecules of  $\text{HCl}$  (12 litres), two molecules of  $\text{PH}_3$  (four litres) are made; hence,

$$\begin{aligned} 12 : 4 :: 10 : x; \\ x = 3.333 \text{ litres of } \text{PH}_3. \end{aligned}$$

4. At  $236^\circ$  phosphorus penta-chloride dissociates into phosphorus tri-chloride and free chlorine. What will be the volume of the mixed gases by the dissociation of five litres of phosphorus penta-chloride?

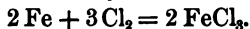


5. When chlorine acts upon ammonia gas, the following occurs : —



From 10 litres of ammonia gas how many litres of nitrogen will be formed, and how much chlorine will be used?

6. From 12 litres of chlorine gas what volume of ferric chloride will be formed?



## II — PERCENTAGE COMPOSITION.

In sulphuric acid ( $\text{H}_2\text{SO}_4$ ) there are two atoms of hydrogen ( $\text{H}_2$ ), one atom of sulphur ( $\text{S}$ ), and four atoms of oxygen ( $\text{O}_4$ ). There are two parts by weight of hydrogen ( $2 \times 1$ ) (since each atom of hydrogen weighs one), 32 parts of sulphur, and 64 ( $16 \times 4$ ) parts of oxygen; hence the molecule of sulphuric acid weighs

$$98 \quad \begin{array}{ccc} \text{H}_2 & \text{S} & \text{O}_4 \\ 2 & 32 & 64 \end{array} \quad \begin{array}{c} \text{H}_2\text{SO}_4 \\ = 98 \end{array}$$

Every molecule of sulphuric acid (98 parts by weight) contains  $\frac{2}{98}$  parts of hydrogen,  $\frac{32}{98}$  parts of sulphur, and  $\frac{64}{98}$  parts of oxygen, or, expressed in terms of per cent, —

$$\begin{array}{rcl} \frac{2}{98} \text{ of } 100 & = & 2.04 \text{ per cent of hydrogen;} \\ \frac{32}{98} \text{ of } 100 & = & 32.65 \text{ per cent of sulphur;} \\ \frac{64}{98} \text{ of } 100 & = & 65.31 \text{ per cent of oxygen.} \\ & & \hline & & 100.00 \end{array}$$

## PROBLEMS.

1. Find percentage composition of barium nitrate ( $\text{BaN}_2\text{O}_6$ ).

$$\begin{array}{rcl} \begin{array}{ccc} 137 & 14 \times 2 & 16 \times 6 \\ \text{Ba} & + 2\text{N} & + 6\text{O} \end{array} & = & \begin{array}{c} 261 \\ \text{BaN}_2\text{O}_6 \end{array} \\ \frac{137}{261} \text{ of } 100 & = & 52.49 \text{ per cent of Ba;} \\ \frac{28}{261} \text{ of } 100 & = & 10.73 \text{ per cent of N;} \\ \frac{96}{261} \text{ of } 100 & = & 36.78 \text{ per cent of O.} \\ & & \hline & & 100.00 \end{array}$$

2. Find the percentage composition of ether ( $\text{C}_4\text{H}_{10}\text{O}$ ).

$$\begin{array}{rcl} \begin{array}{ccc} 48 & 10 & 16 \\ \text{C}_4 & + \text{H}_{10} & + \text{O} \end{array} & = & \begin{array}{c} 74 \\ \text{C}_4\text{H}_{10}\text{O} \end{array} \\ \frac{48}{74} \text{ of } 100 & = & 64.87 \text{ per cent of C.} \\ \frac{10}{74} \text{ of } 100 & = & 13.51 \text{ per cent of H.} \\ \frac{16}{74} \text{ of } 100 & = & 21.62 \text{ per cent of O.} \\ & & \hline & & 100.00 \end{array}$$

3. Find the percentage composition of  $\text{MgNH}_4\text{PO}_4$ ;  $\text{C}_6\text{H}_5\text{NO}_2$ .

### III.—MOLECULAR FORMULÆ FROM THE PERCENTAGE COMPOSITION.

In determining the percentage composition of any compound, we *divide* the weight of any given element in the compound, multiplied by 100, by the molecular weight; the quotient is the per cent of the given element.

In determining the simplest symbol from the percentage composition, we reverse this method; that is, if we *divide the weight of any element in the molecule, multiplied by 100, by the per cent of that element, we will have the molecular weight*. From the molecular weight thus found and the per cent of the other elements, determine the actual weight of each element in the molecule. Divide these weights by the respective atomic weights, and we have the number of atoms of each element. When only the per cent of each element is given, we do not know the weight of any element in the molecule, but we do know that there must be *at least one atom* of each of the elements.

On the supposition that there is only one atom of any of the elements in the substance, we find, as above, the corresponding weight of each of the other elements. Divide these weights by the respective atomic weights; the result is the number of atoms of each element. Every molecule must have at least *one atom* of each element entering into it; neither can it contain any *fractions of atoms*. If fractions of atoms are obtained in the above, they must be changed to the smallest proportionate whole numbers.



## PROBLEMS.

1. The percentage composition of barium nitrate is

$$\text{Ba} = 52.49 \text{ per cent ;}$$

$$\text{N} = 10.73 \text{ per cent ;}$$

$$\text{O} = 36.78 \text{ per cent.}$$

Find the simplest symbol.

Assume the compound to contain one atom of Ba ; then the molecular weight will be 261.

$$\frac{137 \times 100 = (\text{atomic weight of Ba} \times 100)}{x = (\text{molecular weight})} = 52.49 = (\text{per cent of Ba}).$$

Since the molecular weight is 261 (when the compound has 137 parts of Ba, or one atom), there will be

$$261 \times \frac{10.73}{100} = 28 = \text{weight of N,}$$

and

$$261 \times \frac{36.78}{100} = 96 = \text{weight of O ;}$$

then, dividing these weights by the atomic weights,

$$137 \div 137 = 1 \text{ atom of Ba,}$$

$$28 \div 14 = 2 \text{ atoms of N,}$$

$$96 \div 16 = 6 \text{ atoms of O ; or BaN}_2\text{O}_6.$$

2. From the following percentage composition determine the simplest symbol :—

$$\text{C} = 64.87 \text{ per cent ;}$$

$$\text{H} = 13.51 \text{ per cent ;}$$

$$\text{O} = 21.62 \text{ per cent.}$$

Assume the compound to contain one atom of carbon ; then

$$\frac{12 \times 100}{x} = 64.87 ; \quad x = 18.49.$$

Or if the compound has 12 parts by weight of carbon, the

molecular weight will be 18.49, and it will contain  $18.49 \times \frac{13.51}{100}$   
 $= 2.5$  parts by weight of hydrogen; and similarly  $18.49 \times \frac{21.62}{100}$   
 $= 4$  parts by weight of oxygen; then

$$12 \div 12 = 1.00 \text{ atom of C;}$$

$$2.5 \div 1 = 2.50 \text{ atoms of H;}$$

$$4 \div 16 = 0.25 \text{ atom of O.}$$

To get at least one atom of O (since there cannot be less than one atom of O in a compound), multiply by 4. We get  $\text{C}_4\text{H}_{10}\text{O}$ .

3. Determine the simplest formula corresponding to the following percentage composition:—

$$\text{C} = 40; \text{H} = 6.6; \text{O} = 53.4.$$

4. From the following determine the simplest symbol:—

$$\text{C} = 35.64; \text{H} = 1.98; \text{O} = 15.84; \text{Br} = 39.60; \text{N} = 6.91.$$

5. From analysis the following percentage composition was obtained. To what formula does it correspond?

$$\text{N} = 14.27; \text{Mo} = 48.98; \text{O} = 32.65; \text{H} = 4.08.$$



#### IV.—EXPANSION OF GASES.

All gases have practically the same rate of expansion. This rate of expansion has been measured, and it has been found that a gas will increase or decrease  $\frac{1}{273}$  of its volume at  $0^\circ \text{C}$ . for every degree it is heated above  $0^\circ$  or cooled below  $0^\circ$ . Thus, from  $0^\circ$  to  $2^\circ$  it will increase  $\frac{2}{273}$  of its volume at  $0^\circ$ , and at  $273^\circ$  it will be double the volume at  $0^\circ$ .

## PROBLEMS.

1. We have 100 cc. of gas at  $0^{\circ}$ . What will be the volume at  $300^{\circ}$ ?

Represent the required volume by  $V$ ; then

$$V = 100 + 100 \cdot \frac{300}{273} = 100 \left( 1 + \frac{300}{273} \right) = 100 \left( \frac{573}{273} \right);$$

$$\text{or, } V = 100 \frac{573}{273} \text{ at } 300^{\circ}. \quad (\text{I.})$$

2. We have 100 cc. of gas at  $300^{\circ}$ . What will be the volume at  $25^{\circ}$ ?

First find the volume the 100 cc. will be at  $0^{\circ}$ . Let  $V$  = the volume at  $0^{\circ}$ ; then 100, the volume at  $300^{\circ}$ , is the volume at  $0^{\circ}$  ( $V$ ) + the increase ( $V \times \frac{300}{273}$ );

$$\text{or, } 100 = V + V \cdot \frac{300}{273} = V \frac{573}{273};$$

$$V = 100 \frac{273}{573} = \text{volume at } 0^{\circ}. \quad (\text{II.})$$

Now, by (I.) the volume at  $25^{\circ}$  will be

$$V = 100 \frac{273}{573} \times \frac{298}{273} = 100 \frac{298}{573} = \text{volume at } 25^{\circ}. \quad (\text{III.})$$

To find the *degrees of temperature* corresponding to an increase of volume.

3. 200 cc. of a gas at  $25^{\circ}$  has increased in volume to 310 cc. To what temperature was it heated?

$$200 \cdot \frac{273}{298} = \text{volume at } 0^{\circ} \text{ (according to (II.))};$$

$$\text{then } 310 \text{ cc. (volume at } t^{\circ}) = 200 \cdot \frac{273}{298} \cdot \frac{273 + t^{\circ}}{273} = 200 \cdot \frac{273 + t^{\circ}}{298};$$

solve for  $t^{\circ}$ .

To find the *weight of a gas* accompanying a change of temperature.

4. 200 cc. of a gas weighs 10 grms. at  $20^{\circ}$ . What will 200 cc. of this gas weigh at  $210^{\circ}$ ?

Find the volume of the gas at  $210^{\circ}$  by (III.).

$200 \cdot \frac{483}{293} = \text{volume at } 210^{\circ} = 10 \text{ grms.};$  hence 200 cc. will weigh

$$200 \cdot \frac{483}{293} : 200 :: 10 : x;$$

$$x = 10 \cdot \frac{293}{483} = \text{weight of 200 cc. at } 210^{\circ}. \quad (\text{IV.})$$

5. 200 cc. of a gas weighs 10 grms. at  $50^{\circ}$ . What will 300 cc. of it weigh at  $200^{\circ}$ ?

$$200 \cdot \frac{573}{323} = \text{volume of 200 cc. at } 200^{\circ};$$

then  $200 \cdot \frac{573}{323} : 300 :: 10 : x;$

$$x = \frac{300}{200} \cdot 10 \cdot \frac{323}{573} = \text{weight of 300 cc. at } 200^{\circ}.$$

From an inspection of the results in I., II., III., and IV., it will be seen that when the temperature of a gas increases from  $0^{\circ}$ , the volume increases in the ratio of  $\frac{273 + t^{\circ}}{273}$ ; when the temperature decreases from  $t^{\circ}$  to  $0^{\circ}$ , the volume decreases by the ratio of  $\frac{273}{273 + t^{\circ}}$ ; when the temperature increases from a lower ( $t^{\circ}$ ) to a higher ( $t'^{\circ}$ ) degree, or from a higher to a lower degree, the volume increases or decreases as the ratios of  $\frac{273 + t'^{\circ}}{273 + t^{\circ}}$ , or  $\frac{273 + t^{\circ}}{273 + t'^{\circ}}$ . From (IV.) we see that the weight is inversely to these ratios for temperature; hence, in solving the problems, we simply ask ourselves *whether the volume or weight will be increased or diminished, and arrange the fraction accordingly.*

6. A volume of air, measuring 230 cc., was standing in a litre flask over water, the temperature of which was  $26^{\circ}$ . The temperature was then raised to  $60^{\circ}$ . How much water then remained in the flask?

7. I have a litre flask full of hydrogen gas at  $15^{\circ}$ . I wish to expel one-half the gas. To what temperature must it be heated?

8. I have a litre flask full of oxygen, standing over water at  $90^{\circ}$ . I wish 100 cc. of water to enter the flask. What must be the temperature?

9. Three litres of chlorine and five litres of hydrogen gases were mixed and exposed to sunlight at a temperature of  $15^{\circ}$ . It was found, after the chlorhydric acid had been formed, that the temperature had risen to  $40^{\circ}$ . What volume did the gases now occupy?

10. Below  $500^{\circ}$  sulphur has six atoms to the molecule; above  $500^{\circ}$  it has only two atoms to the molecule. We have 300 cc. of sulphur gas at  $450^{\circ}$ . What will be the volume at  $800^{\circ}$ ?



#### V.—VOLUME AND WEIGHT OF GASES AFFECTED BY PRESSURE.

All gases possess the property of expansibility and compressibility, and the rate of expansion or compression is the same (very nearly) for all gases. It can be shown by experiment that if we *increase* the pressure on any given volume of a gas, the volume will *decrease*, and if we decrease the pressure, the volume will *increase*. The increase in volume accompanying a decrease in pressure, and the decrease in volume accompanying an increase in

pressure, have been measured, and it is found that *the volume varies inversely as the pressure.*

From this law it follows that *the weight of any gas will vary directly as the pressure.* Thus, if we have 100 cc. of a gas at 760 mm. pressure, at 800 mm. the volume will be

$$100 : x :: 800 : 760 ; \quad x = 95 \text{ cc. ;}$$

and if 100 cc. of this gas weighs (say) 10 grms. at a pressure of 760 mm., at 800 mm. 95 cc. of this gas will weigh 10 grms.; and hence 100 cc. of the gas at 800 mm. pressure will weigh more, or

$$10 : x :: 760 : 800 ; \quad x = 10.52 \text{ grms.}$$

#### PROBLEMS.

1. What will be the volume of 650 cc. of air at 76 cm. pressure when the barometer stands at 72 cm.?

Since the volumes are inversely proportional to the pressure, we have

$$650 : x :: 72 : 76.$$

2. A volume of gas weighs 13 grms. at a pressure of 76 cm. What will the same volume of gas weigh at a pressure of 140 cm.?

Since the weight varies directly as the pressure, we have

$$13 : x :: 76 : 140.$$

3. A cubic decimeter of a gas weighs 5 grms. when the barometer stands at 750 mm. Under what pressure will a cubic decimeter of the same gas weigh 7 grms.? Under what pressure will a cubic meter weigh 10 grms.?

4. We have a litre flask full of hydrogen gas under a pressure of 750 mm. What pressure must be applied to reduce the volume to 300 cc.?



5. 10 litres of chlorine gas at  $25^{\circ}$  and 76 cm. pressure was heated to  $710^{\circ}$ . What pressure will be required to convert this gas at  $710^{\circ}$  back to the original 10 litres?



## VI.—RELATION BETWEEN WEIGHT AND VOLUME OF GASES.

A litre of hydrogen gas at  $0^{\circ}$  and 76 cm. pressure weighs .0896 grms. The litre of chlorine gas, under the same conditions, weighs 3.1808 grms.; or, using the litre of hydrogen as a standard of comparison, we see that the chlorine is  $\frac{3.1808}{.0896} = 35.5$  times as heavy as hydrogen, or its sp. gr. is 35.5. From the law that *equal volumes of all gases contain the same number of molecules*, it follows that the weights of all gases are to each other as their molecular weights.

The molecular weight of hydrogen is 2;

The molecular weight of chlorine is 70;

therefore hydrogen is to chlorine as 2 : 70, or as 1 : 35.5.

The molecular weight of oxygen is 32;

hence hydrogen is to oxygen as 2 : 32, or as 1 : 16.

The molecular weight of arsenic is 300;

hence hydrogen is to arsenic as 2 : 300, or as 1 : 150.

Thus we see that chlorine is 35.5; oxygen, 16; and arsenic 150 times as heavy as hydrogen; or the sp. gr. of chlorine is 35.5; oxygen, 16; and arsenic, 150.

But 35.5 is half the molecular weight of chlorine,

16 is half the molecular weight of oxygen, and

150 is half the molecular weight of arsenic;

therefore *the specific gravity is equal to one-half the molecular weight of a gas*; or the molecular weight of a gas is twice the specific gravity referred to hydrogen.

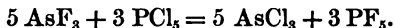
## PROBLEMS.

1. The molecular weight of bromine is 160. What is the sp. gr.?

2. What will two litres of each of the following gases weigh: arsenic? chlorine? alcohol? benzol?

3. What will be the volume of phosphorus vapor at  $420^{\circ}$ , obtained from 3 grms. of solid phosphorus?

4. How much phosphoric fluoride by volume can be obtained from 100 grms. of phosphorus penta-chloride?



Suppose all the products to be gases.

5. How many cubic centimetres of solid arsenic (sp. gr. 5.72) could be obtained from 1250 cc. of arseniuretted hydrogen at a temperature of  $105^{\circ}$ ?



6. What volume of hydrogen and oxygen would be obtained by decomposing 10 grms. of water into its component elements at  $0^{\circ}$  and 76 cm.?

## VII.—SPECIFIC GRAVITY OR VAPOR DENSITY OF GASES.

The specific gravity or vapor density of a gas, or a substance capable of being converted into a gas, is the weight of a given volume of the gas compared with the weight of the same volume of air under the same conditions of temperature and pressure.

### TO DETERMINE THE VAPOR DENSITY OF LIQUIDS.

*Dumas' Method.*—A thin glass globe, having a very small drawn-out neck, is filled with dry air and weighed,



the temperature and pressure being noted at the time of weighing. A small quantity of the given substance is then introduced into the globe. The globe is then immersed up to the neck in a liquid whose boiling-point is considerably above that of the substance inside the globe. The bath is then heated, the temperature being raised  $30^{\circ}$ – $40^{\circ}$  after the substance in the globe begins to boil. When no more gas issues from the globe, the end of the drawn-out neck is quickly sealed by melting the glass together, noting the temperature of the bath and the barometric pressure at the same time. The globe is then removed from the bath, cleaned and dried, and, when cool, weighed. To determine the volume of the globe, the end of the neck is broken off under distilled water at  $4^{\circ}$ , when the globe should completely fill with water, which is then weighed. This weight gives the volume of the globe in cubic centimetres. This will furnish the experimental data from which the specific gravity can be calculated.

1. On determining the vapor density of aniline, the following data was obtained:—

The globe full of dry air at  $16^{\circ}$  and 760 mm. pressure weighed 30.273 grms. The globe full of aniline vapor at  $215^{\circ}$  and 763.2 mm. weighed 30.5058 grms. The contents of the globe was 210 cc. What is the vapor density?

1 cc. of dry air at  $0^{\circ}$  weighs .001293 grms.; then the weight of the air in the globe at  $16^{\circ}$  was  $.001293 \times 210 \times \frac{273}{289} = .2564$  grms. The empty globe weighs  $30.273 - .2564 = 30.0166$  grms.

The aniline vapor weighs  $30.5058 - 30.0166 = 0.4892$  grms.

210 cc. of dry air at  $215^{\circ}$  and 763.2 mm. weighs

$$.001293 \times \frac{273}{488} \times \frac{763.2}{760} \times 210 = .1522.$$

$$\text{Vapor density} = \frac{.4892}{.1522} = 3.214. \quad \text{Ans.}$$

2. On determining the vapor density of ether, the following data were obtained. Calculate the sp. gr. of the gas.

Weight of globe full of air at 19° and a pressure of 741.5 mm. = 49.632 grms. Weight of globe full of vapor at 82.5° and a pressure of 740.3 mm. = 49.995 grms. Weight of globe full of water = 325.61 grms. *Ans.* 2.6.

3. On determining the vapor density of mercuric chloride, the following data were obtained. To what molecular formula does this lead?

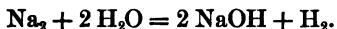
Weight of globe full of air at 18° and 759 mm. = 26.318 grms. Weight of globe full of vapor at 350° and 758.4 mm. = 27.401 grms. Capacity of globe = 250 cc.

4. Determine the vapor density of phosphorus tri-chloride from the following data:—

Weight of globe full of air at 16° and 740 mm. = 39.812 grms. Weight of globe full of vapor at 100° and 761 mm. = 40.773 grms. Capacity of globe = 280 cc.



## VIII. — QUANTITATIVE PROBLEMS.



In the reaction above, one molecule of sodium has acted upon two molecules of water, and there has been formed two molecules of sodium hydrate and one molecule of hydrogen, or 46 parts by weight of sodium have acted upon 36 parts by weight of water to form 80 parts of sodium hydrate and 2 parts of hydrogen; that is, every reaction shows not only the number of atoms, but also the parts by weight of the different substances which enter into it.

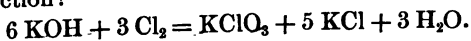
## PROBLEMS.

1. How much sodium hydrate can be made from 10 grms. of sodium according to the above reaction?

By the reaction (which shows us the proportions by which sodium and water act upon each other) we see that Na<sub>2</sub> (46 parts by weight) act upon water to form 2 NaOH (80 parts by weight), or 46 grms. of sodium furnish 80 grms. of sodium hydrate; hence 10 grms. of sodium will furnish

$$46 : 80 :: 10 : x; x = 17.39 \text{ grms. of sodium hydrate.}$$

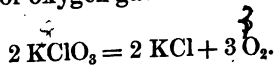
2. How much potassium chlorate (KClO<sub>3</sub>) can be made from 150 grms. of potassium hydrate (KOH) according to the following reaction?



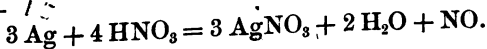
By the reaction we see that 6 KOH (336 parts by weight) furnish KClO<sub>3</sub> (122.5 parts by weight), or 336 grms. of KOH yield 122.5 grms. of KClO<sub>3</sub>; hence, 150 grms. will yield

$$336 : 122.5 :: 150 : x; x = 54.68 \text{ grms. of KClO}_3.$$

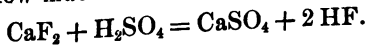
3. What weight of oxygen gas can be obtained from 10 grms. of KClO<sub>3</sub>?



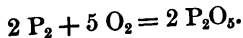
4. How much AgNO<sub>3</sub> can be obtained from 15 grms. of Ag, and how much H<sub>2</sub>O and how many litres of NO gas, under standard conditions, will be formed according to the following:—



5. 10 litres of hydrofluoric acid gas were made from CaF<sub>2</sub> and H<sub>2</sub>SO<sub>4</sub>. How much CaSO<sub>4</sub> was made at the same time?

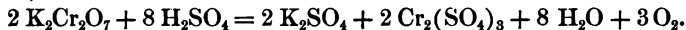


6. How many litres of air will be required to burn 5 grms. of phosphorus?



7. What weight of potassium can be obtained from 20 grms. of alum ( $K_2Al_2(SO_4)_4$ , 24  $H_2O$ ) ?

8. What volume of oxygen gas, measured at  $15^\circ$  and 772 mm. pressure, can be obtained from 100 cc. of sulphuric acid (sp. gr. 1.84) ?



9. Water will absorb 1050 times its volume of ammonia gas. How many grammes of ammonium chloride will be required to furnish the gas sufficient to saturate 500 cc. of water ?



## IX. — ATOMIC WEIGHT DETERMINATIONS.

In the table at the end of the chapter, the method by which the atomic weights of the elements have been determined is indicated, and there will be found the data on which these important numbers are based.

### METHOD BASED ON THE MOLECULAR WEIGHT

(determined from the vapor density, by the application of Avogadro's Law) of a series of gaseous compounds containing the element, and the percentage composition of these compounds, determined by analysis. Thus, we wish to determine the atomic weight of chlorine. The vapor density of all the simple gaseous compounds containing chlorine has been determined. This gives the molecular weight, since the molecular weight is twice the vapor density, referred to hydrogen. The percentage composition of all the above gaseous compounds is now determined by analysis. Now determine the actual weight of chlorine in a molecule of the different substances from the molecular weight and percentage composition. The smallest weight

of chlorine which is thus found in any of the compounds is then the atomic weight of chlorine.

The necessary data is found in the following table:—

ATOMIC WEIGHT OF CHLORINE.

| SUBSTANCE.                                 | VAPOR DENSITY. | MOLECULAR WEIGHT. | PER CENT OF CHLORINE. | WEIGHT OF CHLORINE. |
|--------------------------------------------|----------------|-------------------|-----------------------|---------------------|
| HCl . . . . .                              | 18.185         | 36.37             | 97.25                 | 35.37               |
| NOCl . . . . .                             | 32.67          | 65.34             | 54.13                 | 35.37               |
| PCl <sub>3</sub> . . . . .                 | 68.535         | 137.07            | 77.41                 | 106.11              |
| AsCl <sub>3</sub> . . . . .                | 90.5           | 181               | 58.62                 | 106.11              |
| C <sub>2</sub> H <sub>5</sub> AsCl . . . . | 70.01          | 140.02            | 25.22                 | 35.37               |
| CH <sub>3</sub> Cl . . . . .               | 25.17          | 50.34             | 70.26                 | 35.37               |
| SiCl <sub>4</sub> . . . . .                | 84.75          | 169.5             | 83.46                 | 141.48              |
| ZnCl <sub>2</sub> . . . . .                | 67.8           | 135.6             | 52.17                 | 70.74               |

The smallest weight of chlorine found in any of these compounds is 35.37, the other weights being always some multiple of this; hence we conclude that the compound containing 35.37 parts of chlorine, contains only one *atom* of chlorine, and that 35.37 is the atomic weight of chlorine. In the table will be found a list of the elements whose atomic weights have been thus determined.



## X.—METHOD OF THE SPECIFIC HEAT.

It has been found by experiment that if we heat equal weights of any two elements, as of iron and lead, between any two temperatures, as from 0° to 1°, a different number of heat units will be required in each case. Thus,

the amount of heat required to raise the temperature of one kilogramme of lead or iron  $1^{\circ}$ , would raise the temperature of one kilogramme of water  $.0314^{\circ}$  and  $.112^{\circ}$  respectively. We express this by saying the specific heat of lead is .0314, and iron .112. The *specific heat is the number of units of heat absorbed by a body in raising the temperature of that body  $1^{\circ}$ , compared with the number of units of heat absorbed by water in raising its temperature the same  $1^{\circ}$ .* After the specific heat of a number of the elements had been made, it was found that by multiplying the specific heats of the elements by their respective atomic weights, very nearly the same product was obtained in each case.

That is, *the product of the atomic weight by the specific heat is a constant, approximately 6.4.*

This furnished a new method for determining the atomic weights. We *divide the constant 6.4 by the specific heat of the element, and we have the atomic weight.* For example: the specific heat of iron is .112; what is the atomic weight?

$$6.4 \div .112 = 57.1,$$

atomic weight of iron, which, although not exactly correct (55.9 being the accepted weight), shows us it cannot be some multiple of 55.9, which we could not tell from analysis alone. This method can be applied, directly, only to the solid elements. The specific heat of many of the elements varies considerably at different temperatures, and this may account for the variations from the true atomic weights by this method.

### XI. — METHOD OF ISOMORPHISM.

It has been found that substances of entirely different composition often have the same crystalline form, and hence we sometimes assume that substances having the same crystalline form have analogous compositions; thus magnesium, barium, and calcium carbonates have the same crystalline form. The atomic weight of Mg can be determined from its specific heat; and if we assume that in magnesium carbonate there is *one* atom of Mg, then in calcium carbonate and barium carbonate there will also be one atom of Ca and Ba; and knowing this from the percentage composition, we can determine the atomic weights of these elements. This method is of but little practical value, as it is based on an assumption, and then it has been found that many substances having the same crystalline form do not have analogous compositions. It is, however, the only means for determining the atomic weight of some of the elements.

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### XII. — MOLECULAR WEIGHT DETERMINATIONS.

For the determination of the molecular weight of the elements, and for many compounds, we rely upon the physical method based upon the deduction from the law of Avogadro, that *the molecular weight is twice the vapor density* referred to hydrogen.

This method is only applicable in the case of those elements and compounds whose vapor density can be determined.

It is the only method for determining the molecular weight, and hence the number of atoms to the molecule, of the elements.

In the case of those compounds whose vapor density cannot be determined, a molecular weight is assigned to them, based upon the results of analysis, and upon their analogy to compounds whose molecular weight has been determined by the vapor density method.

| ELEMENT.          | SOME COMPOUNDS WHOSE VA-<br>POR DENSITY HAS BEEN<br>DETERMINED.                          | SPECIFIC<br>HEAT. | ATOMIC WEIGHT.          |                         |                     |
|-------------------|------------------------------------------------------------------------------------------|-------------------|-------------------------|-------------------------|---------------------|
|                   |                                                                                          |                   | By<br>Vapor<br>Density. | By<br>Specific<br>Heat. | By<br>Anal-<br>ogy. |
| Hydrogen . . .    | HF, HCl, HBr, HI                                                                         | ...               | ...                     | ...                     | ..                  |
| Lithium . . . .   | none                                                                                     | 0.941             | ...                     | 7.                      | ..                  |
| Beryllium . . .   | none                                                                                     | 0.408             | ...                     | 9.1                     | ..                  |
| Boron . . . . .   | BF <sub>3</sub> , BCl <sub>3</sub> , BBr <sub>3</sub> , B(CH <sub>3</sub> ) <sub>3</sub> | 0.254             | 11.                     | 11.                     | ..                  |
| Carbon . . . .    | CH <sub>4</sub> , CH <sub>3</sub> Cl, CO <sub>2</sub>                                    | 0.174             | 12.                     | 12.                     | ..                  |
| Nitrogen . . .    | NH <sub>3</sub> , NO, NO <sub>2</sub> , NOCl                                             | ...               | 14.                     | ...                     | ..                  |
| Oxygen . . . .    | H <sub>2</sub> O, N <sub>2</sub> O, CO, SO <sub>2</sub>                                  | ...               | 15.96                   | ...                     | ..                  |
| Fluorine . . . .  | HF, F(CH <sub>3</sub> ), SiF <sub>4</sub>                                                | ...               | 19.                     | ...                     | ..                  |
| Sodium . . . .    | none                                                                                     | 0.293             | ...                     | 23.                     | ..                  |
| Magnesium . .     | none                                                                                     | 0.245             | ...                     | 24.3                    | ..                  |
| Aluminum . .      | AlCl <sub>3</sub> , Al(CH <sub>3</sub> ) <sub>3</sub>                                    | 0.202             | 27.                     | 27.                     | ..                  |
| Silicon . . . . . | SiCl <sub>4</sub> , SiH <sub>3</sub> Cl, SiF <sub>4</sub>                                | 0.165             | 28.                     | 28.                     | ..                  |
| Phosphorus . .    | PH <sub>3</sub> , PCl <sub>3</sub> , PF <sub>3</sub> , POCl <sub>3</sub>                 | 0.189             | 31.                     | 31.                     | ..                  |
| Sulphur . . . .   | H <sub>2</sub> S, SO <sub>2</sub> , SO <sub>3</sub> , CS <sub>2</sub>                    | 0.178             | 32.                     | 32.                     | ..                  |
| Chlorine . . . .  | HCl, ZnCl <sub>2</sub> , HgCl <sub>2</sub>                                               | ...               | 35.4                    | 39.                     | ..                  |
| Potassium . .     | none                                                                                     | 0.166             | ...                     | ...                     | ..                  |
| Calcium . . . .   | none                                                                                     | 0.170             | ...                     | 39.9                    | ..                  |
| Scandium . . .    | none                                                                                     | ...               | ...                     | ...                     | 44.                 |
| Titanium . . .    | TiCl <sub>4</sub>                                                                        | ...               | 48.                     | ...                     | ..                  |



| ELEMENT.         | SOME COMPOUNDS WHOSE VA-<br>POR DENSITY HAS BEEN<br>DETERMINED. | SPECIFIC<br>HEAT. | ATOMIC WEIGHT.          |                         |                     |
|------------------|-----------------------------------------------------------------|-------------------|-------------------------|-------------------------|---------------------|
|                  |                                                                 |                   | By<br>Vapor<br>Density. | By<br>Specific<br>Heat. | By<br>Anal-<br>ogy. |
| Vanadium . . .   | $\text{VCl}_3, \text{VOCl}_3$                                   | ...               | 51.1                    | ...                     | ..                  |
| Chromium . .     | $\text{CrO}_2\text{Cl}_2$                                       | 0.100             | 52.2                    | 52.2                    | ..                  |
| Manganese . .    | none                                                            | 0.122             | ...                     | 54.9                    | ..                  |
| Iron . . . . .   | $\text{FeCl}_3$                                                 | 0.112             | 55.9                    | 55.9                    | ..                  |
| Nickel . . . . . | none                                                            | 0.108             | ...                     | 58.5                    | ..                  |
| Cobalt . . . . . | none                                                            | 0.107             | ...                     | 58.7                    | ..                  |
| Copper . . . .   | $\text{Cu}_2\text{Cl}_2$                                        | 0.093             | 63.1                    | 63.1                    | ..                  |
| Zinc . . . . .   | $\text{ZnCl}_2, \text{Zn}(\text{CH}_3)_2$                       | 0.093             | 65.2                    | 65.2                    | ..                  |
| Gallium . . . .  | $\text{Ga}_2\text{Cl}_6$                                        | 0.079             | 69.7                    | 69.7                    | ..                  |
| Germanium . .    | $\text{GeCl}_4, \text{GeI}_4$                                   | ...               | ...                     | 72.3                    | ..                  |
| Arsenic . . . .  | $\text{AsH}_3, \text{As}_2\text{O}_3, \text{AsCl}_3$            | 0.082             | 74.8                    | 74.8                    | ..                  |
| Selenium . . .   | $\text{SeH}_2, \text{SeO}_2$                                    | 0.080             | 78.9                    | 78.9                    | ..                  |
| Bromine . . . .  | $\text{HBr}, \text{CH}_3\text{Br}, \text{CdBr}_2$               | 0.084             | 79.8                    | 79.8                    | ..                  |
| Rubidium . . .   | none                                                            | ...               | ...                     | ...                     | 85.2                |
| Strontium . . .  | none                                                            | ...               | ...                     | ...                     | 87.3                |
| Yttrium . . . .  | none                                                            | ...               | ...                     | ...                     | 89.5                |
| Zirconium . . .  | $\text{ZrCl}_4$                                                 | 0.066             | 90.5                    | 90.5                    | ..                  |
| Niobium . . . .  | $\text{NbCl}_5, \text{NbOCl}_3$                                 | ...               | 94.                     | ...                     | ..                  |
| Molybdenum . .   | $\text{MoCl}_5$                                                 | 0.072             | 95.6                    | 95.6                    | ..                  |
| Ruthenium . .    | none                                                            | 0.061             | ...                     | 103.5                   | ..                  |
| Rhodium . . .    | none                                                            | 0.058             | ...                     | 104.1                   | ..                  |
| Palladium . . .  | none                                                            | 0.059             | ...                     | 105.6                   | ..                  |
| Silver . . . . . | none                                                            | 0.056             | ...                     | 107.7                   | ..                  |

| ELEMENT.         | SOME COMPOUNDS WHOSE VA-<br>POR DENSITY HAS BEEN<br>DETERMINED. | SPECIFIC<br>HEAT. | ATOMIC WEIGHT.          |                         |                     |
|------------------|-----------------------------------------------------------------|-------------------|-------------------------|-------------------------|---------------------|
|                  |                                                                 |                   | By<br>Vapor<br>Density. | By<br>Specific<br>Heat. | By<br>Anal-<br>ogy. |
| Cadmium . . .    | $\text{CdBr}_2$                                                 | 0.054             | 111.8                   | 111.8                   | ..                  |
| Indium . . . .   | $\text{InCl}_3$                                                 | 0.057             | 113.5                   | 113.5                   | ..                  |
| Tin . . . . .    | $\text{SnCl}_2, \text{SnCl}_4, \text{Sn}_2\text{Cl}_6$          | 0.054             | 117.9                   | 117.9                   | ..                  |
| Antimony . . .   | $\text{SbH}_3, \text{SbCl}_3, \text{Sb}(\text{CH}_3)_3$         | 0.052             | 120.                    | 120.                    | ..                  |
| Tellurium . . .  | $\text{TeH}_2$                                                  | 0.047             | 124.7                   | 124.7                   | ..                  |
| Iodine . . . . . | $\text{HI}, (\text{CH}_3)\text{I}, \text{HgI}_2$                | 0.054             | 126.5                   | 126.5                   | ..                  |
| Cæsium . . . .   | none                                                            | ...               | ...                     | ...                     | 132.5               |
| Barium . . . .   | none                                                            | ...               | ...                     | ...                     | 136.7               |
| Lanthanum . .    | none                                                            | 0.045             | ...                     | 138.5                   | ..                  |
| Cerium . . . .   | none                                                            | 0.045             | ...                     | 141.1                   | ..                  |
| Didymium . .     | none                                                            | 0.045             | ...                     | 146.                    | ..                  |
| Ytterbium . .    | none                                                            | ...               | ...                     | ...                     | 172.7               |
| Tantallum . .    | $\text{TaCl}_5$                                                 | ...               | 182.3                   | ...                     | ..                  |
| Tungsten . . .   | $\text{WOCl}_4, \text{WCl}_5, \text{WCl}_6$                     | 0.033             | 183.5                   | 183.5                   | ..                  |
| Osmium . . . .   | $\text{OsO}_4$                                                  | 0.031             | 192.                    | 192.                    | ..                  |
| Iridium . . . .  | none                                                            | 0.032             | ...                     | 192.6                   | ..                  |
| Platinum . . .   | none                                                            | 0.032             | ...                     | 194.5                   | ..                  |
| Gold . . . . .   | none                                                            | 0.032             | ...                     | 196.5                   | ..                  |
| Mercury . . . .  | $\text{HgCl}_2, \text{HgI}_2, \text{Hg}(\text{CH}_3)_2$         | 0.032             | 199.7                   | 199.7                   | ..                  |
| Thallium . . .   | $\text{TlCl}$                                                   | 0.033             | 203.6                   | 203.6                   | ..                  |
| Lead . . . . .   | $\text{PbCl}_2, \text{Pb}(\text{CH}_3)_4$                       | 0.031             | 206.4                   | 206.4                   | ..                  |
| Bismuth . . . .  | $\text{BiCl}_3, \text{BiF}_3, \text{Bi}(\text{CH}_3)_3$         | 0.030             | 207.5                   | 207.5                   | ..                  |
| Thorium . . . .  | none                                                            | 0.027             | ...                     | 232.5                   | ..                  |
| Uranium . . .    | $\text{UCl}_4, \text{UBr}_4$                                    | 0.027             | 239.                    | 239.                    | ..                  |

## PROBLEMS

1. Draw up a table similar to the one in the text, of the gaseous compounds containing oxygen, and from it determine the atomic weight of oxygen, supposing you knew the percentage composition of the compounds.

2. Analysis gives the following results:—

Boron tri-chloride = 9.4 per cent B, 90.6 per cent Cl;

Boron tri-bromide = 4.4 per cent B, 95.6 per cent Br.

From the table, the specific gravity of these compounds can be determined. What is the atomic weight of boron?

3. What proof have you that the atomic weight of phosphorus is 31? How is the atomic weight of silicon determined?

4. By analysis we find that for every 100 parts of silver bromide there are 57.44 parts of Ag and 42.56 parts of Br. The atomic weight of Br = 79.8. What is the atomic weight of silver? What other data is necessary in order to solve the problem? and give your reasons for accepting it.

5. The specific heat of phosphorus is .189. The vapor density of phosphorus referred to hydrogen is 62. How many atoms are there in the molecule of phosphorus gas?

6. In every 100 parts of nitric acid there are 1.58 parts of H, 76.19 parts of O, and 22.23 parts of N. Does this fix the formula of the acid? Why do we accept the formula  $\text{HNO}_3$ ?

7. The specific gravity of mercuric chloride referred to air is 9.8. It contains 73.93 per cent of Hg and 26.07 per cent of Cl. To what symbol does this lead for mercuric chloride?

8. The specific gravity of mercurous chloride is 8.3. It contains 84.92 per cent of Hg and 15.08 per cent of chlorine. To what symbol would this correspond for mercurous chloride? Why is the symbol usually written  $\text{Hg}_2\text{Cl}_2$ ?

9. We find from analysis that barium chloride contains 65.86 per cent of Ba and 34.14 per cent of Cl. There are no compounds of Ba whose vapor density has been determined. The specific heat of Ba is unknown. How would you determine the atomic weight of Ba?

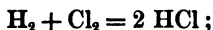
10. By analysis we find aluminum methyl to contain 37.5 per cent of Al, 50 per cent of C, and 12.48 per cent of H. The specific gravity referred to hydrogen is very nearly 72 at 160°, but at 220° it is found to be nearly 36. Can you account for the specific gravity varying at the two temperatures? What is the formula of the compound?



### XIII. — REACTIONS.

When chlorine and hydrogen gases unite, chlorhydric acid gas is formed. We know this to be true by performing the experiment. If we *measured* the chlorine and hydrogen used and the chlorhydric acid gas formed, we would find that for every *one* volume of hydrogen and *one* volume of chlorine used, *two* volumes of chlorhydric acid gas would be formed.

If we had *weighed* the hydrogen and chlorine used and the chlorhydric acid formed, we would find that for every 1 part by weight of hydrogen and 35.5 parts by weight of chlorine used, 36.5 parts by weight of chlorhydric acid would result. The three above *facts* can be expressed briefly by a single equation, thus:—



that is, every properly written equation will represent—

1st. The substances which enter into the reaction, and the products which are formed as a result of the action.

- 2d. The parts by weight of all the substances which appear in the reaction.
- 3d. When the substances which appear in the reaction are gases, the parts by volume of the respective gases; and hence the substances should be written to represent molecules as far as it is possible to do so.

In order to express any facts in chemistry by a reaction, we must know: 1. What substances take part in the reaction and what substances are formed by the action. 2. We must know the symbol of a molecule of each substance appearing in the reaction.

We can then determine the number of molecules of each substance (by repeated trials), or, as it is usually called, — balancing the reaction, — to take such quantities of each substance, that the sum of the atoms in the substances used shall equal the sum of the respective atoms in the substances formed.

Thus, when chlorine is passed into a solution of potassium hydrate, we know *as a result of experiment* (not because we can so write the reaction) that potassium chloride, potassium chlorate, and water are formed.

We would express it thus: —

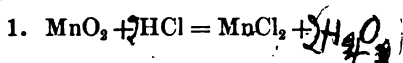


To determine the number of molecules of each substance which must appear in order to form the given substances, we *balance* the reaction, and we have: —



#### PROBLEMS.

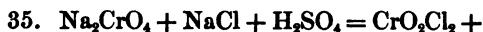
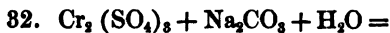
In the following equations supply the factors or products, and have the reactions balance: —



PROBLEMS.

ol a. + 44  
27

2.  $\text{MnO}_2 + \text{NaCl} + \text{H}_2\text{SO}_4 = \text{MnSO}_4 + \text{Na}_2\text{SO}_4 + \text{H}_2\text{O}$
3.  $\text{K}_2\text{Cr}_2\text{O}_7 + \text{HCl} = \text{Cr}_2\text{Cl}_6 + \text{KCl} + \text{H}_2\text{O} + \text{O}_2$
4.  $\text{KClO}_3 + \text{HCl} = \text{KClO} + \text{H}_2\text{O} + \text{O}_2$
5.  $\text{MnO}_2 + \text{KBr} + \text{H}_2\text{SO}_4 = \text{Br}_2 +$
6.  $\text{H}_2\text{S} + \text{I}_2 =$
7.  $\text{K}_2\text{Cr}_2\text{O}_7 + \text{H}_2\text{SO}_4 = \text{Cr}_2(\text{SO}_4)_3 + \text{O}_2 +$
8.  $\text{NH}_3 + \text{Cl}_2 = \text{NH}_4\text{Cl} +$
9.  $\text{HNO}_3 + \text{H}_2 = \text{NO} + \text{H}_2\text{O}.$
10.  $\text{HNO}_3 + \text{H}_2 = \text{H}_2\text{O} + \text{NH}_3.$
11.  $\text{NH}_4\text{Cl} + \text{MgO} =$
12.  $\text{PH}_3 + \text{HI} =$
13.  $\text{CS}_2 + \text{H}_2\text{S} + \text{Cu} = \text{Cu}_2\text{S} + \text{CH}_4.$
14.  $\text{NaC}_2\text{H}_3\text{O}_2 + \text{NaOH} = \text{CH}_4 +$
15.  $\text{SiO}_2 + \text{CaF}_2 + \text{H}_2\text{SO}_4 = \text{CaSO}_4 + \text{H}_2\text{O} + \text{SiF}_4.$
16.  $\text{HNO}_3 + \text{SO}_2 + \text{H}_2\text{O} = \text{H}_2\text{SO}_4 +$
17.  $\text{HNO}_3 + \text{Zn} = \text{Zn}(\text{NO}_3)_2 + \text{H}_2\text{O} + \text{NH}_4\text{NO}_3.$
18.  $\text{As}_2\text{S}_3 + \text{K}_2\text{S} =$
19.  $\text{As}_2\text{S}_5 + \text{K}_2\text{S} =$
20.  $\text{CO}_2 + \text{K} = \text{C} +$
21.  $\text{K}_4\text{Fe}(\text{CN})_6 + \text{H}_2\text{SO}_4 + \text{H}_2\text{O} = \text{CO} +$
22.  $\text{AlCl}_3 + \text{K} =$
23.  $\text{KOH} + \text{Br}_2 =$
24.  $\text{Ca}(\text{NO}_3)_2 + \text{K}_2\text{CO}_3 =$
25.  $\text{KNO}_3 + \text{S} + \text{C} = \text{K}_2\text{S} + \text{CO}_2 + \text{N}_2.$
26.  $\text{K}_2\text{CO}_3 + \text{H}_2\text{O} + \text{CO}_2 =$
27.  $\text{CaO}_2\text{H}_2 + \text{Cl}_2 =$
28.  $\text{CaCO}_3 + \text{H}_2\text{SO}_4 =$
29.  $\text{Al}_2\text{Cl}_6 + \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} =$
30.  $\text{Al}_2\text{Cl}_6 + (\text{NH}_4)_2\text{S} + \text{H}_2\text{O} =$
31.  $\text{SnCl}_2 + \text{Na}_2\text{CO}_3 + \text{H}_2\text{O} =$



Write the reactions representing : —

1. The manufacture of chlorhydric acid from NaCl.
2. The manufacture of  $\text{HNO}_3$  from  $\text{NaNO}_3$ .
3. The manufacture of  $\text{H}_2\text{SO}_4$  from  $\text{FeS}_2$ .
4. The manufacture of HI from I.
5. The manufacture of  $\text{H}_2\text{SiF}_6$  from  $\text{CaF}_2$ .
6. The manufacture of  $\text{H}_2\text{CrO}_4$  from  $\text{Cr}_2\text{O}_3$ .
7. The manufacture of  $\text{HMnO}_4$  from  $\text{MnO}_2$ .
8. The manufacture of  $\text{H}_3\text{PO}_4$  from P.
9. The manufacture of  $\text{H}_2\text{S}$  from S.
10. The manufacture of pure O from the air.
11. The manufacture of  $\text{KNO}_3$  from KCl.
12. The manufacture of  $\text{K}_2\text{CO}_3$  from KCl.
13. The manufacture of  $\text{KClO}_3$  from KOH.
14. The manufacture of  $\text{K}_2\text{MnO}_4$  from  $\text{MnO}_2$ .
15. The manufacture of  $\text{K}_2\text{Mn}_2\text{O}_8$  from  $\text{Mn}_2\text{O}_3$ .
16. The manufacture of NaOH from  $\text{Na}_2\text{CO}_3$ .
17. The manufacture of  $\text{Na}_2\text{CO}_3$  from NaCl.
18. The manufacture of  $\text{NaHCO}_3$  from NaCl.
19. The manufacture of  $\text{Na}_2\text{O}$  from  $\text{Na}_2\text{SO}_4$ .
20. The manufacture of  $\text{HgCl}$  from Hg.
21. The manufacture of  $\text{AgNO}_3$  from AgCl.
22. The manufacture of  $\text{Fe}_2\text{Cl}_6$  from  $\text{FeCl}_3$ .
23. The manufacture of  $\text{Fe}_2(\text{SO}_4)_3$  from FeS.
24. The manufacture of Br from KBr.
25. The manufacture of  $\text{SbH}_3$  from Sb.

## XIV. — THERMO-CHEMISTRY.

When hydrogen combines with oxygen, heat is set free ; when hydrogen combines with iodine, heat is absorbed ; and so it is with every other chemical reaction, — heat is either set free or absorbed. The quantity of heat developed or absorbed can be measured. The unit of heat is called a *Calorie*. *It is the quantity of heat necessary to raise one kilogramme of water through one degree Centigrade.* Thus if the statement be made that by the union of hydrogen and oxygen, 68,360 calories are set free, it means that by the union of 2 grms. of hydrogen gas with 16 grms. of oxygen gas, enough heat is set free to raise the temperature of 68,360 kilogrammes of water from (say) 18° to 19° Centigrade. When hydrogen and iodine unite, 6040 calories are absorbed. This means that by the union of 1 gram. of hydrogen with 127 grms. of iodine, heat is not given off, but is absorbed, and consequently heat must be given to it, to bring about the reaction. We use the following methods of expressing these reactions:—

1.  $[H_2, O] = 68,360 +$ , or  $H_2 + O = H_2O + 68,360 \text{ cal.}$
2.  $[H, I] = 6040 -$ , or  $H + I = HI - 6040 \text{ cal.}$
3.  $[SO_2, O, H_2O] = 55,000 +$ , or  $SO_2 + O + H_2O = H_2SO_4 + 55,000 \text{ cal.}$

This latter represents the number of calories developed when 64 grms. of sulphur dioxide, 16 grms. of oxygen, and 18 grms. of water, combine to form 98 grms. of liquid sulphuric acid.

In expressing the result of a reaction in calories, more is implied than the mere expression of the heat developed or absorbed. It further tells us the comparative affinity with which these elements or compounds unite, and this



affinity is called the *energy of combination*. The number of calories express the exact amount of chemical and physical work in a chemical reaction. By the chemical work the composition of the compound is altered, and the physical work serves to alter the aggregate condition, its condensation, etc. From this statement, first expressed by Berthelot, we see that the heat set free by a reaction is exactly equal to that amount of energy (heat) which would be necessary to again split up the compound into its elements. If the union of sulphur and oxygen to form gaseous  $\text{SO}_2$  sets 71,070 calories free, then it would require exactly 71,070 calories to again convert it into S and  $2\text{O}_2$ , or 71,070 calories would be absorbed in this decomposition.

In all the measurements, both temperature and pressure must be taken into consideration.

"If a series of simple bodies or compounds undergo a physical or chemical change under fixed conditions, the amount of heat developed or absorbed is dependent upon the condition of the elements or compounds at the beginning or end of the experiment.

The heat absorbed upon decomposing a compound is equal to that which is developed by the union of the decomposed parts to form the compound, if the initial and final conditions be similar.

The amount of heat developed by a series of reactions is equal to the sum obtained by taking the reactions singly, and these various steps may either take place simultaneously or in succession.

A chemical reaction which takes place without the assistance of some external force (heat, electricity, light, etc.) tends to form that body or bodies at whose formation the largest amount of heat is set free. From which it naturally follows that a chemical reaction will take

place without the assistance of some external force, if by the union of the various elements or compounds heat would be developed."

A knowledge, therefore, of the thermic relation of elements and compounds furnishes us the satisfactory explanation of reactions, and enables us to predict the possibility of others.

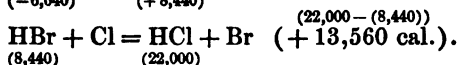
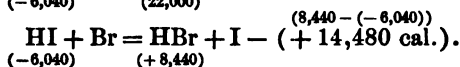
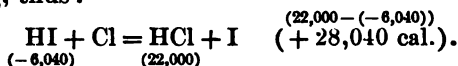
How evident the action of chlorine upon hydrogen-iodide becomes when we consider it from a thermo-chemical standpoint, —



Hydrogen and iodine combine with difficulty, and the combination is only effected by the constant addition of heat. The compound will naturally not be near as stable, more easily decomposed, than one whose formation is accompanied by heat. It can therefore be easily explained why chlorine should replace iodine in HI, since,

$$[\text{H}, \text{I}] = -6040 \text{ cal.}, \text{ and } [\text{H}, \text{Cl}] = +22,000.$$

We may write the equation, giving the thermo-chemical sign of the equation, which can be obtained by deducting from the heat of formation of the products that of those reacting, thus: —



Many reactions take place by the direct union of the element or compounds, and, at ordinary temperature, such reactions are called "*direct*" or *exothermic reactions*. Often, however, a small amount of some external force, such as

heat, light, or electricity, is necessary to start the reaction, which then of its own accord becomes complete with either greater or less activity. Thus by heating with a flame for a short time, or exposing for a few minutes to sunlight, or perhaps by passing an electric current through the mixture, the reaction can be started. We have as an example the union of hydrogen and oxygen, which unite with such great force and such an enormous development of heat, brought about by an electric spark, or the union of hydrogen and chlorine, at whose union 22,000 calories are developed is occasioned by the exposure for a second to sunlight. A chemical reaction may also be assisted by pressure or jarring the mixture; but all these mechanical assistants can be shown to be the cause of the development of heat, which upon being communicated to the mixture causes their union.

The decomposition of a compound at whose formation heat was absorbed is called "*direct*" or *exothermic decomposition*. If by means of a jar, a flame, or an electric spark, the decomposition be started, the remainder of the compound will decompose in consequence of the heat developed. Nearly all explosive bodies come under this category: thus the slightest jar will cause nitrogen per-chloride ( $\text{NCl}_5$ ) to decompose with great violence; the decomposition being started, the entire quantity will decompose.

If the union of two elements or compounds is accompanied by the absorption of heat, the reaction is said to be *endothermic* or *indirect*. Such reactions require the continued assistance of external force, and the heat absorbed in the reaction must be given to it direct, either in a certain number of calories, or indirectly by means of light or electricity.

When  $\text{N}_2$  and O combine to form gaseous  $\text{N}_2\text{O}$ , 18,320

calories are absorbed, when N and O combine to nitric oxide, NO, 21,575 calories are absorbed, and the formation of hypochlorous oxide,  $\text{Cl}_2\text{O}$ , is accompanied by the absorption of 18,040 calories.

To decompose a compound at whose formation heat was set free, an amount of heat equal to that which was developed at its formation must be applied. Such decomposition is called *endothermic*, and can only be called forth by the assistance of some external force.



#### XV.—SOLUTION AND HYDRATION.

If a gas be passed into water and only a very small volume be absorbed, the absorption is recognized as a purely physical operation. Whereas if large quantities be absorbed, as in the case of hydrochloric acid gas or ammonia gas, a chemical change is thought to have taken place. The amount of gas which any liquid can absorb varies with the temperature and pressure. We can best explain the retention of small amounts of gas in a liquid upon which it has no chemical action, by imagining the space between the molecules of the liquid filled with these gas particles. The greater the pressure, the greater will be the amount the liquid can hold in suspension. The same liquid absorbs different gases unequally, and inversely the same gas is unequally soluble in various liquids, so that the absolute amount of absorbed gas is dependent upon the chemical nature of the liquid and the gas. Bunsen's laws governing solubility of gases may be condensed to the three following:—

I. For the same gas, the same liquid, and the same tem-

perature, the weight of gas absorbed is proportional to the pressure.

II. The quantity of gas absorbed decreases with the increase of temperature.

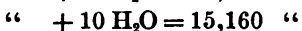
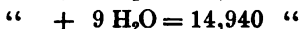
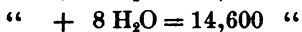
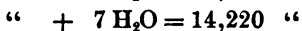
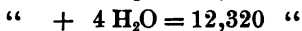
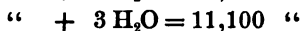
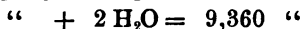
III. The quantity of gas which a liquid can dissolve is independent of the nature and quantity of other gases which it may already hold in solution. Water will dissolve just as much oxygen from the air (of which it forms one-fifth part) as it would if the oxygen were alone and the pressure equal to one-fifth of the atmosphere.

The heat produced by merely physical absorption of gases is not sufficient to be measured with any accuracy.

When a measurable amount of heat is absorbed or developed upon the absorption of a gas by a liquid, a chemical change usually takes place. Here we are forced to recognize the existence of some affinity between the gas and liquid molecules. Berthelot found that the amount of chemical change is dependent upon the relative mass of water, the dissolved compound, and the temperature. When hydrochloric acid gas combines with two molecules of water, Berthelot found that 3490 calories more heat was developed than when HCl combined with 5 H<sub>2</sub>O, and 4650 calories more than when it combined with 10 H<sub>2</sub>O.

If we bring two liquids, such as water and mercury, in contact with each other, which do not mix, then no absorption or development of heat is noticeable; the opposite becomes evident upon the mixture of two liquids which dissolve one another. When either nitric acid or sulphuric acid is dissolved in water, heat is developed. The cause of this development is best explained by the supposition that new compounds are formed by the union of one acid molecule with one, two, or three, etc., molecules of water. Investigation shows that the amount of heat

developed is dependent upon the amount of water with which the acid combines. Thus Berthelot found:—



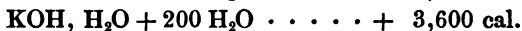
From this we see that the amount of heat developed upon the addition of one  $\text{H}_2\text{O}$  to  $\text{H}_2\text{SO}_4$  equals + 6280 calories, the addition of the second molecule is only accompanied by 3080 calories, while the addition of one molecule of  $\text{H}_2\text{O}$  to  $\text{H}_2\text{SO}_4 + 9 \text{H}_2\text{O}$  causes development of only 220 calories. The change of amount of heat diminishes so rapidly after the first few molecules, that we may justly consider that the hydrates, as  $\text{S}(\text{OH})_6$ ,  $\text{SO}(\text{OH})_4$  and  $\text{SO}_2(\text{OH})_2$ , to merely pass in solution without further chemical change.



#### XVI.—SOLUTION OF SOLIDS IN WATER.

The solution of solids increase with the increase of temperature.

When potassium oxide dissolves in water, potassium hydrate is formed. According to the amount of heat developed by this reaction, it seems more than plausible that more than the mono-hydrates of  $\text{K}_2\text{O}$  is formed.



That with the dissolving of KOH, 2 H<sub>2</sub>O heat should be absorbed, may be explained by the large amount of energy necessary to dissolve so large a molecule, or that the water causes a decomposition of this hydrate.

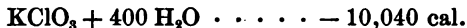
In but few salts do we find the water of crystallization held with equal firmness. Thus in the ordinary sodium phosphate (Na<sub>2</sub>HPO<sub>4</sub> + 12 H<sub>2</sub>O), we find that two of the twelve molecules of water of crystallization are held more firmly than the remaining ten. This can be explained. When Na<sub>2</sub>HPO<sub>4</sub> combines with its first two molecules of water, the average amount of heat developed is 3015 calories, whereas the average amount of heat developed upon the addition of the other ten molecules only amounts to 2044. This is more clearly shown with sodium carbonate. Thomsen found that —



With such data we can easily see why sodium carbonate upon being heated does not part with all the molecules of water of crystallization with the same ease. That MgSO<sub>4</sub>, 7 H<sub>2</sub>O gives off 6 H<sub>2</sub>O at 150°, and the last not until 250° is reached, that ZnSO<sub>4</sub>, 7 H<sub>2</sub>O requires a red heat to drive off the last molecule of water, while the remaining six separate at 100°, can be explained similarly to the explanation given for sodium carbonate. In all these examples it is shown that a certain number of the molecules of water of crystallization are bound more firmly than others, and their formation must have been accompanied with considerable more energy.

In dissolving salts which do not form hydrates, and also

hydrated salts which do not combine with water to form higher hydrates, heat is absorbed.



When an anhydrous salt dissolves in water, heat is developed with the formation of a hydrated salt; but upon dissolving this hydrated salt in water, heat is absorbed. Anhydrous calcium chloride dissolves in water, and 17,410 calories are set free. When, however, the hydrate  $\text{CaCl}_2, 6 \text{ H}_2\text{O}$  passes into solution, 4340 calories of heat are absorbed. The higher the state of hydration, the greater will be the amount of heat absorbed when the hydrate passes into solution.

Sodium sulphate dissolves with the development of 460 calories.  $\text{Na}_2\text{SO}_4, \text{H}_2\text{O}$  dissolves in water with an absorption of 1900 calories, and  $\text{Na}_2\text{SO}_4, 10 \text{ H}_2\text{O}$  with an absorption of 18,760 calories.



## XVII — NEUTRALIZATION.

Since the heat of reaction is simply a measurement of the molecular work performed, it is evident that the heat developed upon neutralizing an acid with a base, or a base with an acid, furnishes us with definite data in determining the comparative strengths of acids and bases.

In order to determine the basicity of an acid by thermochemical means, it becomes necessary to have different



quantities and varying strengths of solutions to act upon it.

The following contains the heat of neutralization of some of the most important acids with sodium hydrate:—

|                                           |             |
|-------------------------------------------|-------------|
| HCl . . . . .                             | 27,480 cal. |
| HBr . . . . .                             | 27,500 cal. |
| HI . . . . .                              | 27,350 cal. |
| H <sub>2</sub> S . . . . .                | 15,480 cal. |
| HNO <sub>3</sub> . . . . .                | 27,360 cal. |
| H <sub>2</sub> SO <sub>4</sub> . . . . .  | 31,380 cal. |
| H <sub>2</sub> CrO <sub>4</sub> . . . . . | 24,720 cal. |
| H <sub>2</sub> SO <sub>3</sub> . . . . .  | 28,970 cal. |
| H <sub>2</sub> CO <sub>3</sub> . . . . .  | 20,180 cal. |
| H <sub>3</sub> PO <sub>3</sub> . . . . .  | 27,080 cal. |

Thomsen separates the commoner acids into four distinct groups:—

I. Those producing heat of neutralization approximating to 20,000 calories; such as, HNO<sub>3</sub>, HClO, H<sub>2</sub>CO<sub>3</sub>, etc.

II. Those acids whose heat approximates to 25,000 calories; as, H<sub>2</sub>CrO<sub>4</sub>, etc.

III. Acids whose heat of neutralization is nearly equal to 27,000 calories; as, HCl, HBr, HI, HClO<sub>3</sub>, HBrO<sub>3</sub>, HNO<sub>3</sub>.

IV. And finally those greater than 27,000, and varying from 28,000 to 32,500 calories; as, H<sub>2</sub>SO<sub>3</sub>, H<sub>2</sub>SO<sub>4</sub>, H<sub>2</sub>SeO<sub>4</sub>, HF, HPO<sub>3</sub>, etc.

In neutralizing the bases with acids, the heat of neutralization of such bases as NaOH, KOH, etc., averages about 31,350 calories; while the neutralization of anhydrous bases, such as NH<sub>3</sub>, the amines, the heat averages about 28,000 calories.

It is noticeable that in neutralizing the various bases with the same acid, we find the hydrates of lithium, sodium and potassium; of barium, strontium and calcium; of manganese and nickel, cobalt and iron, etc., run in groups, giving among themselves very nearly the same amount of heat of neutralization.

| SUBSTANCE.     |                                                                | HEAT OF<br>FORMATION. | HEAT OF<br>SOLUTION AT<br>18°. | NUMBER<br>OF MOLECULES<br>OF WATER. |
|----------------|----------------------------------------------------------------|-----------------------|--------------------------------|-------------------------------------|
| <i>Acids.</i>  | H, Cl Gas . . . .                                              | 22,000 cal.           | 17,310                         | 300                                 |
|                | H, Br " . . . .                                                | 8,440                 | 19,940                         | 400                                 |
|                | H, I " . . . .                                                 | -6,040                | 19,210                         | 500                                 |
|                | H <sub>2</sub> , S " . . . .                                   | 4,510                 | 4,750                          | 900                                 |
|                | H, N, O <sub>3</sub> " . . . .                                 | 34,000                | 7,150                          | 200                                 |
|                | N <sub>2</sub> , O <sub>6</sub> , H <sub>2</sub> O " . . . .   | -200                  | ...                            | ...                                 |
|                | H <sub>2</sub> O, SO <sub>3</sub> Liquid . . . .               | 21,320                | 16,920                         | ...                                 |
|                | H <sub>2</sub> , S, O <sub>4</sub> " . . . .                   | 192,910               | 16,920                         | ...                                 |
|                | P <sub>2</sub> , O <sub>5</sub> , 3 H <sub>2</sub> O " . . . . | 395,080               | 10,420                         | ...                                 |
|                | P <sub>2</sub> , O <sub>5</sub> , 3 H <sub>2</sub> O " . . . . | 244,180               | 5,880                          | ...                                 |
| <i>Oxides.</i> | CrO <sub>3</sub> , H <sub>2</sub> O " . . . .                  | 580                   | ...                            | ...                                 |
|                | K <sub>2</sub> , O . . . . .                                   | 97,200                | 67,400                         | ...                                 |
|                | Na <sub>2</sub> , O . . . . .                                  | 100,200               | 55,000                         | ...                                 |
|                | Ca, O . . . . .                                                | 132,000               | 18,100                         | ...                                 |
|                | Fe, O . . . . .                                                | 69,000                | ...                            | ...                                 |
|                | Fe <sub>2</sub> , O <sub>3</sub> . . . . .                     | 191,200               | ...                            | ...                                 |
|                | Ni, O . . . . .                                                | 61,400                | ...                            | ...                                 |
|                | Co, O . . . . .                                                | 64,000                | ...                            | ...                                 |
|                | Zn, O . . . . .                                                | 86,400                | ...                            | ...                                 |
|                | Pb, O . . . . .                                                | 51,000                | ...                            | ...                                 |

|                   | SUBSTANCE.                                                      | HEAT OF FORMATION. | HEAT OF SOLUTION AT 18°. | NUMBER OF MOLECULES OF WATER. |
|-------------------|-----------------------------------------------------------------|--------------------|--------------------------|-------------------------------|
| <i>Oxides.</i>    | Cu, O . . . . .                                                 | 38,400             | ...                      | ...                           |
|                   | Hg, O . . . . .                                                 | 31,000             | ...                      | ...                           |
|                   | Ag, O . . . . .                                                 | 5,900              | ...                      | ...                           |
|                   | H <sub>2</sub> , O . . . . .                                    | 68,360             | ...                      | ...                           |
|                   | S, O <sub>2</sub> . . . . .                                     | 71,070             | 7,700                    | ...                           |
|                   | C, O . . . . .                                                  | 28,590             | ...                      | ...                           |
|                   | C, O <sub>2</sub> . . . . .                                     | 96,960             | 5,880                    | ...                           |
| <i>Hydrates.</i>  | K <sub>2</sub> , O, H <sub>2</sub> O . . . . .                  | 129,600            | 35,000                   | ...                           |
|                   | Na <sub>2</sub> , O, H <sub>2</sub> O . . . . .                 | 135,600            | 19,600                   | ...                           |
|                   | Ca, O, H <sub>2</sub> O . . . . .                               | 147,000            | 3,100                    | ...                           |
|                   | Sr, O, H <sub>2</sub> O . . . . .                               | 148,600            | 9,600                    | ...                           |
|                   | Al <sub>2</sub> , O <sub>3</sub> , 3 H <sub>2</sub> O . . . . . | 391,600            | ...                      | ...                           |
|                   | Cu, O, H <sub>2</sub> O . . . . .                               | 38,000             | ...                      | ...                           |
| <i>Chlorides.</i> | K, Cl . . . . .                                                 | 105,610            | -4,440                   | 200                           |
|                   | Na, Cl . . . . .                                                | 97,690             | -1,180                   | 100                           |
|                   | NH <sub>3</sub> , HCl . . . . .                                 | 41,910             | -3,880                   | 200                           |
|                   | Ca, Cl <sub>2</sub> . . . . .                                   | 170,230            | 17,410                   | 300                           |
|                   | Ca, Cl <sub>2</sub> , 6 H <sub>2</sub> O . . . . .              | 191,980            | -4,340                   | 400                           |
|                   | Ba, Cl <sub>2</sub> . . . . .                                   | 194,250            | 2,070                    | 400                           |
|                   | Al <sub>2</sub> , Cl <sub>3</sub> . . . . .                     | 321,870            | 153,690                  | 2,500                         |
|                   | Fe, Cl <sub>2</sub> . . . . .                                   | 82,050             | 17,900                   | 350                           |
|                   | Pb, Cl <sub>2</sub> . . . . .                                   | 82,770             | -6,800                   | 1,800                         |
|                   | Zn, Cl <sub>2</sub> . . . . .                                   | 97,210             | 15,630                   | 300                           |
|                   | Hg, Cl . . . . .                                                | 82,550             | ...                      | ...                           |
|                   | Hg, Cl <sub>2</sub> . . . . .                                   | 63,160             | -3,300                   | 300                           |
|                   | Ag, Cl . . . . .                                                | 29,380             | ...                      | ...                           |

| SUBSTANCE.        |                                                                   | HEAT OF<br>FORMATION. | HEAT OF<br>SOLUTION AT<br>18°. | NUMBER<br>OF MOLECULES<br>OF WATER. |
|-------------------|-------------------------------------------------------------------|-----------------------|--------------------------------|-------------------------------------|
| <i>Bromides.</i>  | K, Br. . . . .                                                    | 95,310                | -5,080                         | 200                                 |
|                   | Na, Br . . . . .                                                  | 85,770                | -190                           | 200                                 |
|                   | Cd, Br <sub>2</sub> . . . . .                                     | 73,930                | 440                            | 400                                 |
|                   | Ag, Br . . . . .                                                  | 22,700                | ...                            | ...                                 |
| <i>Iodides.</i>   | K, I . . . . .                                                    | 80,130                | -5,110                         | 200                                 |
|                   | Na, I . . . . .                                                   | 69,080                | 1,220                          | 200                                 |
|                   | Pb, I <sub>2</sub> . . . . .                                      | 39,670                | ...                            | ...                                 |
|                   | Cd, I <sub>2</sub> . . . . .                                      | 44,910                | -960                           | 400                                 |
|                   | Hg, I <sub>2</sub> . . . . .                                      | 34,310                | ...                            | ...                                 |
|                   | Ag, I . . . . .                                                   | 13,800                | ...                            | ...                                 |
| <i>Sulphides.</i> | K <sub>2</sub> , S . . . . .                                      | 102,200               | 10,200                         | ...                                 |
|                   | Na <sub>2</sub> , S . . . . .                                     | 88,400                | 14,800                         | ...                                 |
|                   | Fe, S . . . . .                                                   | 23,800                | ...                            | ...                                 |
|                   | Cu <sub>2</sub> , S . . . . .                                     | 20,200                | ...                            | ...                                 |
|                   | Cu, S . . . . .                                                   | 10,200                | ...                            | ...                                 |
|                   | Hg, S . . . . .                                                   | 19,800                | ...                            | ...                                 |
|                   | Ag <sub>2</sub> , S . . . . .                                     | 5,310                 | ...                            | ...                                 |
| <i>Sulphates.</i> | K <sub>2</sub> , O <sub>2</sub> , SO <sub>2</sub> . . . . .       | 273,560               | -6,380                         | 400                                 |
|                   | Na <sub>2</sub> , O <sub>2</sub> , SO <sub>2</sub> . . . . .      | 257,510               | 460                            | 400                                 |
|                   | Ca, O <sub>2</sub> , SO <sub>2</sub> . . . . .                    | 248,970               | ...                            | ...                                 |
|                   | Mg, O <sub>2</sub> , SO <sub>2</sub> . . . . .                    | 231,230               | 20,280                         | 400                                 |
|                   | Mg, O <sub>2</sub> , SO <sub>2</sub> , 7 H <sub>2</sub> O . . . . | 255,310               | -3,800                         | 400                                 |
|                   | Pb, O <sub>2</sub> , SO <sub>2</sub> . . . . .                    | 145,130               | ...                            | ...                                 |
|                   | Zn, O <sub>2</sub> , SO <sub>2</sub> . . . . .                    | 158,990               | 18,430                         | 400                                 |
|                   | Zn, O <sub>2</sub> , SO <sub>2</sub> , 7 H <sub>2</sub> O . . . . | 181,680               | -4,260                         | 400                                 |
|                   | Fe, O <sub>2</sub> , SO <sub>2</sub> , 7 H <sub>2</sub> O . . . . | 169,040               | -4,510                         | 400                                 |

|                    | SUBSTANCE.                                                       | HEAT OF FORMATION. | HEAT OF SOLUTION AT 18°. | NUMBER OF MOLECULES OF WATER. |
|--------------------|------------------------------------------------------------------|--------------------|--------------------------|-------------------------------|
| <i>Nitrates.</i>   | { Cu, O <sub>2</sub> , SO <sub>2</sub> . . . . .                 | 111,490            | 15,800                   | 400                           |
|                    | { K, N, O <sub>3</sub> . . . . .                                 | 118,700            | -8,520                   | 200                           |
|                    | { Na, N, O <sub>3</sub> . . . . .                                | 110,600            | -5,030                   | 200                           |
|                    | { N <sub>2</sub> , O <sub>2</sub> , H <sub>4</sub> . . . . .     | 87,900             | -6,320                   | 200                           |
|                    | { Pb, N <sub>2</sub> , O <sub>3</sub> . . . . .                  | 105,600            | -7,610                   | 400                           |
|                    | { Ag, N, O <sub>3</sub> . . . . .                                | 28,700             | -5,440                   | 200                           |
| <i>Carbonates.</i> | { K <sub>2</sub> , O <sub>2</sub> , CO . . . . .                 | 250,940            | 6,490                    | 400                           |
|                    | { Na <sub>2</sub> , O <sub>2</sub> , CO . . . . .                | 242,490            | 5,640                    | 400                           |
|                    | { Na <sub>2</sub> , O <sub>2</sub> , CO, 10 H <sub>2</sub> O . . | 264,290            | -16,160                  | 400                           |
|                    | { Ca, O <sub>2</sub> , CO . . . . .                              | 240,660            | ...                      | ...                           |
|                    | { Mn, O <sub>2</sub> , CO . . . . .                              | 180,690            | ...                      | ...                           |
|                    | { Pb, O <sub>2</sub> , CO . . . . .                              | 139,690            | ...                      | ...                           |
|                    | { H, Na, C, O <sub>3</sub> . . . . .                             | 227,000            | -4,270                   | ...                           |

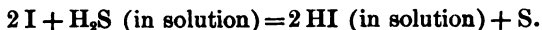
## PROBLEMS.

1. When H and I combine to form hydrogen iodide, 6040 cal. are absorbed; when HI passes into solution in water, 19,210 cal. are given off. The heat of formation of H<sub>2</sub>S in solution is +9260 cal. Knowing those facts, would a chemical change take place when H<sub>2</sub>S is passed into water containing finely pulverized iodide?

If H, I = -6040 cal., and H, I + water = +19,210 cal.; then 19,210 - 6040 = 13,170 cal. must represent the amount of heat developed in the formation of HI in solution. Since HI alone is accompanied by an absorption of heat, and HI in passing into solution a development of heat, it naturally follows that the final amount of heat developed when HI is made in solu-

tion will be the sum of its heat of formation and heat of solution.

Let us now write the equation of what might take place: —



The union of 2 HI in solution would be accompanied by a development of  $2 \times 13,170$  cal. ;  $\text{H}_2\text{S}$  in solution is only represented by + 9260 cal. Since the tendency in every chemical reaction to form that compound whose formation is accompanied by the greatest energy (heat), it will naturally follow that the iodine will act upon the  $\text{H}_2\text{S}$ , decompose it, and form a compound representing greater heat development. The amount of heat necessary to decompose  $\text{H}_2\text{S}$  in solution is represented by the amount of heat developed in its formation (+ 9260 cal.), so that when the HI in solution is formed, the 9260 cal. are first overcome, the reaction consequently giving a final heat of  $(2 \times 13,170 - 9260)$  cal. = 17,080 cal. The reaction is therefore exothermic, and will consequently take place without the assistance of some external energy.

2. How many calories of heat are given off when  $\text{CaBr}_2$ , 6  $\text{H}_2\text{O}$  is formed from  $\text{CaBr}_2$ ?

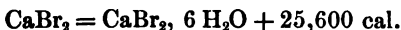
$\text{CaBr}_2$  dissolves in 400 molecules of water, setting 24,510 cal. free.

$\text{CaBr}_2$ , 6  $\text{H}_2\text{O}$  dissolves in 400 molecules of water, absorbing 1090 cal.

The equations would then be: —

$\text{CaBr}_2 + 400 \text{ mol. water} = \text{CaBr}_2 \text{ (in solution)} + 24,510 \text{ cal.}$

$\text{CaBr}_2$ , 6  $\text{H}_2\text{O} + 400 \text{ mol. water} = \text{CaBr}_2 \text{ (in solution)} - 1090 \text{ cal. ;}$   
therefore



In other words, when  $\text{CaBr}_2$ , 6  $\text{H}_2\text{O}$  is made from  $\text{CaBr}_2$ , 25,600 cal. are developed.

3. When chlorine acts upon silver iodide, heat is developed and silver chloride is formed. Why?

$$\text{Ag}_2 + \text{I}_2 = 2 \times 13,800 = + 27,600 \text{ cal.}$$

$$\text{Ag}_2 + \text{Cl}_2 = 2 \times 29,380 = + 58,760 \text{ cal.}$$

$$\therefore 2 \text{ AgI} + \text{Cl}_2 = 2 \text{ AgCl} + \text{I}_2 \dots + 31,160 \text{ cal.}$$

3 a. If, however, silver chloride be acted upon by hydrogen iodide, either in a gaseous condition or in solution, the silver chloride will be completely decomposed and heat will be set free. Why?

We know that

$$\text{Ag}_2, \text{Cl}_2 = + 58,760 \text{ cal.},$$

and

$$\text{Ag}_2, \text{I}_2 = + 27,600 \text{ cal.},$$

$$\begin{aligned} \text{and that } 2 \text{ AgI} + \text{Cl}_2 &= 2 \text{ AgCl} + \text{I}_2 = 58,760 - 27,600 \\ &= + 31,160 \text{ cal.} \end{aligned}$$

It has further been found that

$$\text{Ag}_2\text{O} + 2 \text{ HCl (gas)} = 2 \text{ AgCl} + \text{H}_2\text{O} \dots + 77,220,$$

$$\text{Ag}_2\text{O} + 2 \text{ HI (gas)} = 2 \text{ AgI} + \text{H}_2\text{O} \dots + 102,140;$$

$$\text{that } \text{HCl} + \text{water} = + 17,320,$$

$$\text{and } \text{HI} + \text{water} = + 19,210;$$

therefore

$$\begin{aligned} \text{Ag}_2\text{O} + 2 \text{ HCl (sol.)} &= 2 \text{ AgCl} + \text{H}_2\text{O} \dots + 77,220 - 2 \times 17,320 \\ &= + 42,580 \text{ cal.} \end{aligned}$$

$$\begin{aligned} \text{Ag}_2\text{O} + 2 \text{ HI (sol.)} &= 2 \text{ AgI} + \text{H}_2\text{O} \dots + 102,140 - 2 \times 19,210 \\ &= + 63,720 \text{ cal.} \end{aligned}$$

We have therefore

$$\begin{aligned} 2 \text{ AgCl} + 2 \text{ HI (gas)} &= 2 \text{ AgI} + 2 \text{ HCl(gas)} \dots 102,140 - 77,220 \\ &= + 24,920 \text{ cal.}; \end{aligned}$$

and

$$\begin{aligned} 2 \text{ AgCl} + 2 \text{ HI (sol.)} &= 2 \text{ AgI} + 2 \text{ HCl (sol.)} \dots \\ 63,720 - 42,580 &= + 21,140 \text{ cal.} \end{aligned}$$

(Naumann "Thermo-chemie," p. 496.)

4. What is the heat of formation of  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  made from  $\text{MgSO}_4$ ?

When  $\text{MgSO}_4$  passes into solution, 14,000 cal. are set free; and when  $\text{MgSO}_4 \cdot 7\text{H}_2\text{O}$  dissolves in water, 4000 cal. are absorbed.

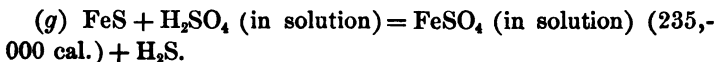
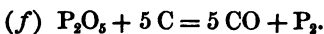
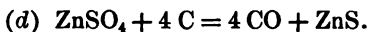
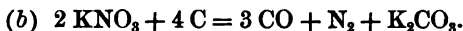
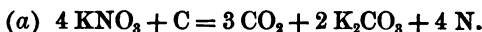
5. With the following data:  $(\text{Ca}, \text{O}_2, \text{CO}) = +240,660$  cal.;  $2\text{HCl}$  (in solution)  $= +2 \times 17,310$  cal.;  $\text{CaCl}_2$  (in solution)  $= +17,410$  cal.;  $\text{H}_2\text{O} = 68,360$  cal.; and  $\text{C}, \text{O}_2 = 96,960$  cal. Can you tell whether the reaction of hydrochloric acid in solution is endothermic or exothermic?

6. Which of the following carbonates can be most easily decomposed, and why?— $\text{PbCO}_3$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{CaCO}_3$ . Is  $\text{ZnCO}_3$  or  $\text{ZnSO}_4$  more easily decomposed?

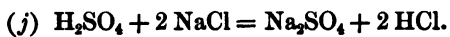
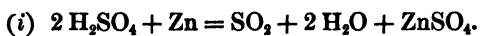
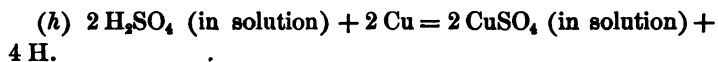
7. How can you explain the following: when oxygen is passed over aluminum chloride (heated), chlorine gas is liberated?  $\text{Al}_2, \text{Cl}_3 = +321,870$  cal.;  $\text{Al}_2\text{O}_3 = 391,600$  cal.

8. According to the heat of formation of  $\text{HgCl}$  and  $\text{HgCl}_2$ , which will be first formed by the action of chlorine upon metallic mercury?

9. Are the following reactions exothermic or endothermic?







**EXAMINATION QUESTIONS AND  
PROBLEMS.**



## ANNUAL EXAMINATION PAPERS.

May, 1878.

1. Calculate the percentage composition of  $\text{H}_2\text{SO}_4$ .
2. How much  $\text{CO}_2$  by weight and by volume could be obtained by heating 500 grms. of pure  $\text{CaCO}_3$ ?
3. How much zinc would be necessary in order to prepare hydrogen enough to fill a balloon of 2 litres capacity, the gas being under standard conditions? [ $\text{Zn} + 2 \text{HCl} = \text{ZnCl}_2 + \text{H}_2$ .]
4. When oxygen and sulphurous anhydride unite to form sulphuric anhydride, what are the relative bulks of the three substances? [ $2 \text{SO}_2 + \text{O}_2 = 2 \text{SO}_3$ .]
5. What is the difference between chemical and physical solution? Give an example of each, and define the terms "saturated solution" and "supersaturated solution."
6. Explain the various uses of the terms "distillation" and "sublimation," and state the distinction generally made between them. Give a good example in each case.
7. Give the chemical names of the following substances: verdigris, vermilion, oil of vitriol, baking soda, washing soda, potash-lye, whiting, white lead, white arsenic, white vitriol, green vitriol, pearlash, cream of tartar, sal-ammoniac, saltpetre. What is a mordant? Give an example.
8. Tell what you can of the occurrence and properties of the following substances; tell what other elements are grouped with each of them, and what is the characteristic of the group: iron, calcium, copper, nitrogen. [Not a qualitative question.]
9. What is the essential difference between chromium in the chromates and in the salts of chromium? What is the difference between the aluminates and the salts of aluminum? What is the difference between the mercurous and the mercuric compounds? Illustrate by symbols in each case.

10. Define the terms "atom" and "molecule." What is a compound radical? a radical substance? How is the so-called ammonium amalgam prepared, and what is the significance of the experiment? What is the difference in meaning between  $2\text{CuCl}$  and  $\text{Cu}_2\text{Cl}_2$ ?

11. Write the symbols of the acetate of iron (ous), iron (ic), bismuth (Bi'''), silver. [Acetic acid is  $\text{HO}(\text{C}_2\text{H}_3\text{O})$ .] What are the essential characteristics of the "acids"?

12. Name the following compounds, and analyze the symbols: —



### May, 1881.

1. Describe as fully as you can the manufacture of sulphuric acid.

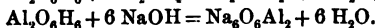
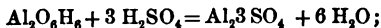
2. What do we understand by "hard" water? What disadvantages does it have, and in what ways, under different circumstances, may hard water be softened? Answer as fully as you can.

3. Explain the use of nitrate of silver in "indelible" ink. Of chloride of cobalt as "invisible" ink. What happens when plaster of Paris "sets"? What when lime is "slaked"?

4. Give the principles on which a single-prism spectroscope is constructed. What advantage has the use of the spectroscope over the "flame-test" in a Bunsen lamp?

5. Explain the various uses of the terms "distillation" and "sublimation," and illustrate fully by examples.

6. Explain the difference between the chromium in these three compounds:  $\text{Cr}_2\text{SO}_4$ ,  $\text{Na}_2\text{O}_6\text{Cr}_2$ ,  $\text{Na}_2\text{CrO}_4$ . Name the compounds. Tell what interesting fact is illustrated by this pair of equations: —



7. Define "oxidation" and "combustion" so as to cover completely the use of the terms.

8. Define "quantivalence." Give examples. How can Pb be bivalent in  $\text{PbO}_2$ ? How Cu bivalent in  $\text{Cu}_2\text{Cl}_2$ ?

9. Given an alloy of lead, silver, and mercury. Devise means for treating the alloy so as eventually to obtain each metal by itself.

10. In what proportion by volume should you expect that the following gases ought to be mixed with air in order to have in each case the most explosive mixture possible: hydrogen, carbon protoxide, carbon bisulphide (as a gas), marsh gas ( $\text{CH}_4$ )? Write equations to represent, as far as it is possible, the chemical actions which take place.

11. When the vapor of alcohol burns in the air, what are the *relative* bulks of the four gaseous substances concerned in the action? [ $\text{C}_2\text{H}_5\text{HO} + 3\text{O}_2 = 2\text{CO}_2 + 3\text{H}_2\text{O}$ .] How many cubic centimetres of carbonic anhydride would be produced by the combustion of 4.6 grms. of alcohol?

12. How many litres of chlorhydric acid gas could be obtained by treating with sulphuric acid a cube of rock salt (sp. gr. = 2.2) measuring 5.5 centimetres each way?

May, 1882.

1. Calculate the percentage composition of  $\text{C}_6\text{H}_5\text{NO}_2$ .

2. How much carbonic anhydride by weight and volume could be made from 350 grms. of  $\text{Na}_2\text{CO}_3$ ?

3. Describe and explain the manufacture on the large scale of sulphuric acid or of carbonate of sodium. Describe the distillation of bituminous coal as fully as you can.

4. Describe the preparation in the laboratory of sulphuric anhydride, of carbon protoxide, of silicic anhydride.

5. How could you separate gold and mercury from each other if they were alloyed together?

6. How is the so-called ammonium amalgam prepared? What is the significance of the experiment?

7. Explain fully the use of the terms "positive" and "negative" as applied to the elements. Give three ways by which the elements may be compared with reference to their electro-chemical characters.

8. How is the vapor density of a substance related to its molecular weight? Having given the vapor density of an elementary substance, what other data must we have in order to determine its probable molecular symbol? Give several examples.

9. Tell all you can about the use of the terms "oxidation" and "reduction."

10. Tell what is meant by "hard" water, and in what ways, under different circumstances, hard water may be softened.

11. Give the chemical names of the following substances: verdigris, vermilion, copperas, oil of vitriol, baking soda, washing soda, potash-lye, whiting, red lead, white arsenic. What is a lake? a mordant?

12. Define quantivalence, and illustrate by an example. Define allotropism. What is the difference between an empirical and a rational formula? Give examples.

13. What is the essential difference between chromium in the chromates and in the salts of chromium? What is the difference between the aluminates and the salts of aluminum?

14. Tell what you can of the appearance and properties of the following metals; tell what other metals are grouped with each of them, and what is the characteristic of the group: aluminum, magnesium, copper, sodium.

**May, 1883.**

1. A solid block of gypsum ( $\text{CaSO}_4 + 2\text{H}_2\text{O}$ ) measures  $.1 \times .2 \times .25$  metre and has a specific gravity of 2.31. What volume in litres would the water of crystallization occupy if set free in the liquid state?

2. How much oxygen by bulk would be required to burn 10 cc. of  $\text{AsH}_3$ ? [ $2\text{AsH}_3 + 6\text{O} = \text{As}_2\text{O}_3 + 3\text{H}_2\text{O}$ .] Solve in the shortest manner possible, and explain fully.

3. Explain the difference between the chromium in these three compounds:  $\text{Cr}_2\text{SO}_4$ ,  $\text{Na}_2\text{O}_6\text{Cr}_2$ ,  $\text{Na}_2\text{CrO}_4$ . Name the compounds. Write the symbols of the corresponding compounds of iron and of aluminum as far as they exist.

4. Why are mercury and copper grouped together? Illustrate by examples. On what supposition might silver be brought into the same group?

5. Define the term "compound radical," and give at least two examples each of a negative and of a positive compound radical. What is a radical substance?

6. Why is "ammonium" classed in the same group with sodium and potassium? Compare the hydrates of sodium and calcium; show any points of similarity and dissimilarity.

7. What is the action of heat on the ammonium compounds? Illustrate by  $\text{NH}_4\text{Cl}$ ,  $(\text{NH}_4)_2\text{SO}_4$ ,  $(\text{NH}_4)\text{NO}_3$ , but make also a general statement.

8. Describe the manufacture of caustic soda by the common process, starting with materials which occur in nature and indicating each step. Write equations where possible.

9. Explain the difference between fractional distillation and fractional condensation. What distinction is usually made between sublimation and distillation? Illustrate by examples.

10. From a solution containing  $\text{CaSO}_4$ ,  $\text{NaCl}$ , and  $\text{MgCl}_2$ , how could you make a rough separation of these three substances and obtain each by itself? Which of the three would be obtained most nearly free from the others?

11. Name the principal substances which cause a water to be "hard," and indicate, in the case of each one, how the water could be softened.

12. The soap-grease men used to buy wood-ashes. Why and what for? What is cream of tartar? For what is it used, and why?

Those who are "conditioned in problems" will do the following example in addition to Nos. 1 and 2.

1 *bis*. How much phosphorus *by weight* is contained in 10 litres of  $\text{PH}_3$  (measured under standard conditions)? How much space would this amount of phosphorus occupy in the gaseous condition? how much in the solid condition? The specific gravity of common phosphorus is 1.83.

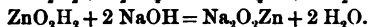
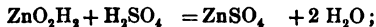
### May, 1884.

1. Give the chemical names of the following substances and the symbols, if possible: vermilion, cinnabar, chrome yellow, Paris green, sugar of lead, soda ash, sal ammoniac, Epsom salt, Glauber's salt, Prussian blue.

2. What are the principal qualitative tests for copper, silver, sulphates, carbonates, nitrates?

3. What is the best solvent for each of the following metals: iron, zinc, lead, aluminum, copper? Write the reaction in each case.

4. Explain these equations, and tell what important fact they illustrate:—



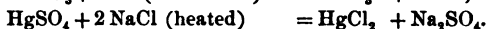
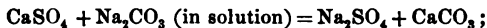
5. Explain the use of the terms "oxidation" and "reduction" in connection with the ferrous and ferric salts, and illustrate by good examples.

6. What is *an* alum? What is *an* alcohol? Illustrate by examples. What do you understand by a *basic chloride* of antimony?



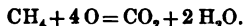
7. Name the following compounds and write the symbols dualistically :  $\text{Ag}_3\text{AsO}_3$ ,  $\text{Na}_3\text{SbS}_4$ ,  $\text{Na}_2\text{Al}_2\text{O}_4$ ,  $\text{Na}_2\text{CS}_3$ ,  $\text{H}_3\text{PO}_4$ .

8. In considering the probability of a metathetical reaction between two salts, what facts is it desirable to know? Thus, which of the following actions should you expect to take place? Why?



9. How much zinc must be dissolved in acid in order to furnish 10 cubic metres of hydrogen gas?  $\text{Zn} + 2 \text{HCl} = \text{ZnCl}_2 + \text{H}_2$ .

10. If one litre of marsh gas ( $\text{CH}_4$ ) be burned, what volume of oxygen will be required for the combustion, and what will be the volume of the carbonic acid produced?



11. How much  $\text{Cr}_2\text{O}_3$  can be formed from 97.35 grms. of  $\text{K}_2\text{CrO}_4$ ?

### May, 1885.

1. Tell all that you know about silver chloride, mercurous chloride, cuprous chloride, cuprous oxide, lead chloride.

2. Explain the use of silver nitrate as a "caustic."

3. Suppose you have three white powders; you know one is  $\text{As}_2\text{O}_3$ , one  $\text{Al}_2\text{O}_3$ , one  $\text{SnO}_2$ , but do you know which is which; how can you tell with certainty?

4. As a rule what will happen when you add  $\text{NaOH}$  to a solution of a salt of a metallic element? Write an equation. Name one good example as an exception. Write the equation.

5. In converting  $\text{MnO}_2$  into  $\text{K}_2\text{MnO}_4$  (and  $\text{Na}_2\text{MnO}_4$ ) by means of a mixture of  $\text{Na}_2\text{CO}_3$  and  $\text{KNO}_3$ , what part does each of these reagents perform?

5. Name several oxides which have been obtained by heating the corresponding nitrates, and write an equation to show what happens in each case.

7. Name two metallic elements whose molecular weight is known. On what evidence does this so-called knowledge rest? Why do we not know the molecular weights of all the elements?

8. Explain fully and illustrate by an example what we mean when we

say that in some compounds zinc plays the part of a positive element and in other compounds the part of a negative element.

9. If gaseous HCl be conducted in water containing bits of marble, how will the bulk of HCl absorbed compare with that of the  $\text{CO}_2$  evolved?  $\text{CaCO}_3 + 2\text{HCl} = \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2$ . Explain your answer fully, and show how it depends on an application of the law of Ampère.

10. How much  $\text{SO}_2$  by bulk could be obtained by treating with  $\text{H}_2\text{SO}_4$  a plate of metallic copper (sp. gr. 8.95) measuring 8 cm.  $\times$  40 cm.  $\times$  44.26 cm.? How many cubic centimetres of  $\text{H}_2\text{SO}_4$  (sp. gr. 1.84) would be required?  $\text{Cu} + 2\text{H}_2\text{SO}_4 = \text{CuSO}_4 + 2\text{H}_2\text{O} + \text{SO}_2$ .

May, 1886.

1. Tell what each of the following substances is — speaking chemically — and give a symbol where possible: black lead, brimstone, blue vitriol, calomel, Glauber's salt, gypsum, cream of tartar, saleratus, quartz, solder, verdigris, vermilion, vinegar.

2. What are — chemically speaking — glass, bricks, mortar, marble, plaster of Paris?

3. For what is hydrogen sulphide commonly employed? If a precipitate of *sulphur* appears when  $\text{H}_2\text{S}$  is passing into a solution, what sort of an action must be taking place?

4. What do we mean by "a typical positive element"? What by "a typical negative element"? Name an element which "sometimes plays a positive and sometimes a negative part in its compounds." Illustrate fully by examples.

5. How could we decide whether the molecular symbol of arsenious oxide should be  $\text{As}_2\text{O}_3$  or  $\text{As}_4\text{O}_6$ ? Explain how we must admit the hypothesis of Avogadro in order to draw our conclusions.

6. Explain fully why we consider copper and mercury members of the same natural group. Why not put tin into the same group? On what principle are groups formed for purposes of qualitative analysis?

7. Tell all you know about hydrogen arsenide; its preparation, properties, symbol, etc.

8. How could you change a ferrous salt in solution to a ferric salt? How could you prove that the change had been accomplished?

9. On general chemical principles, what action should you suppose would take place if the following substances were mixed together:—

(a)  $\text{Ag}_2\text{SO}_4$  and  $\text{BaCl}_2$  (both in solution);

(b)  $\text{NaOH}$  and  $\text{HgCl}_2$  “ “ “

(c)  $\text{Fe}_2\text{Cl}_6$  and  $\text{Na}_2\text{CO}_3$  “ “ “

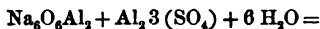
(d)  $\text{KI}$  (solid) and  $\text{H}_2\text{SO}_4$  (strong).

If any other than the expected action takes place, tell what it is.

10. Suppose you have two white powders: one is  $\text{HgCl}_2$  and the other  $\text{Hg}_2\text{Cl}_2$ . How could you tell which is which?

The following question may be substituted for any one of the above except 4, 6, or 9.

A process has recently been patented for purifying sewage by adding aluminate of sodium and sulphate of aluminum. Explain the action between the two chemicals and how it affects the sewage.



### May, 1887.

1. What is the valence of chromium in  $\text{Cr}_2\text{Cl}_6$ ,  $\text{K}_2\text{CrO}_4$ , and  $\text{K}_2\text{Cr}_2\text{O}_7$ ? If  $\text{K}_2\text{CrO}_4$  is chromate of potassium, write the symbol of a perchromate.

2. State what happens when  $\text{H}_2\text{S}$  gas is passed through a solution of  $\text{Fe}_2\text{Cl}_6$  in  $\text{HCl}$ .

3. Give the chemical reactions in the ammonia process for making carbonate of soda.

4. What is the difference between steel, wrought iron, and pig iron? Describe briefly the Bessemer process.

5. What methods would you use to determine if mercury was positive or negative to copper? Explain the use of the terms “positive” and “negative.”

6. State what reactions, if any, would take place on mixing a solution of  $\text{AgNO}_3$  with a solution of  $\text{KClO}_3$ , a solution of  $\text{CaSO}_4$  with a solution of  $\text{BaCl}_2$ , a solution of  $\text{NH}_4\text{Cl}$  with a solution of  $\text{HgSO}_4$ .

7. When  $\text{AgCl}$  is heated on charcoal with  $\text{Na}_2\text{CO}_3$ , state what happens, and explain carefully what the  $\text{Na}_2\text{CO}_3$  is used for.

8. I have a mixture of  $\text{CO}_2$ ,  $\text{N}$  and  $\text{NH}_3$  gases. How can I remove first the  $\text{NH}_3$  and then the  $\text{CO}_2$  and leave the  $\text{N}$  pure?

9. Describe the preparation of  $\text{CO}$ ,  $\text{N}$  and  $\text{SbH}_3$  and mention their properties.

10. If 10 litres of  $\text{C}_2\text{H}_2$  gas be burned to  $\text{CO}_2$  and  $\text{H}_2\text{O}$ , what will be the number of litres of  $\text{O}$  gas required, and what will be the volume of  $\text{CO}_2$  and water formed?

11. What qualitative tests have you had for salts of copper, silver, mercury, and iron; carbonates, sulphides, and sulphocyanates?

12. Give the chemical names, and symbols where possible, of pearl-ash, zinc white, Glauber salts, Epsom salts, bleaching powder, vermilion, litharge, and copperas.



## CONDITION EXAMINATION PAPERS.

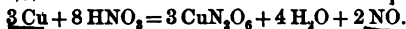


September, 1874.

1. How could you prove experimentally that when charcoal burns in the air it is not destroyed, but that the product formed is actually heavier than when unburnt?

2. Name the principal products of the distillation of soft coal. Why could not anthracite coal be used in the manufacture of illuminating gas?

3. How much nitrogen protoxide by weight and volume could be made by the action of an unlimited amount of nitric acid on 95.1 grms. of copper?



4. Give a method of somewhat general application for determining the equivalent weights of the various elements. How do the equivalent weights differ from the atomic weights?

5. If copper is bivalent, how do you account for the series of compounds,  $\text{Cu}_2\text{O}$ ;  $\text{Cu}_2\text{Cl}_2$ ;  $\text{Cu}_2\text{S}$ ? How are these compounds distinguished by name from  $\text{CuO}$ ;  $\text{CuCl}_2$ ;  $\text{CuS}$ ?

6. Write the symbol of the molecule of oxygen, phosphorus, chlorhydric acid, mercury, potassium, marsh gas, nitric acid.

7. How is vinegar made from alcohol? What is the nature of the action concerned?

8. Of what manufacturing operation is glycerine a waste product? How does nitro-glycerine differ from glycerine?
9. What is mortar; glass; plaster of Paris; clay?
10. Write out a general formula for an alum.

**September, 1883.**

1. Describe as fully as you can the manufacture of sulphuric acid on the large scale. Tell what impurities the commercial oil of vitriol usually contains, and tell all that you have learned about the substance from your own experiments in the laboratory.

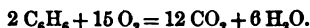
2. Describe the preparation of liquid nitrogen peroxide, of carbon protoxide, of hydrogen arsenide. Give the marked properties of each of these three substances.

3. How could you prove conclusively that the diamond, graphite, and charcoal are merely allotropic modifications of one and the same substance?

4. If you had a mixture of carbonic anhydride and nitrogen, how could you remove the former completely so as to leave the latter pure?

5. A solid block of gypsum ( $\text{CaSO}_4 + 2\text{H}_2\text{O}$ ) measures  $.1 \times .2 \times .25$  metre and has a specific gravity of 2.31. What volume in litres would the water of crystallization occupy if set free in the liquid state?

6. How many cubic centimetres of oxygen would it take to burn 75 cc. of benzol vapor, and how much space would the  $\text{CO}_2$  formed occupy? How much would the water formed weigh?



7. Under what conditions does the same number express both the *specific gravity* and the *atomic weight* of an elementary substance? Answer carefully.

8. What relation does an anhydride bear to the corresponding acid? Illustrate by two examples.

9. The specific gravity of air referred to hydrogen is 14.42. How does this show that air is not a compound having a symbol  $\text{N}_4\text{O}$ ? What other reasons have we for regarding air as a mechanical mixture and not as a chemical compound?

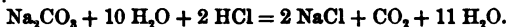
10. Write the symbol for the molecule of oxygen, of phosphorus, and of mercury, and state clearly the reasons for your belief in each case.

11. Explain the difference between the chromium in these three compounds:  $\text{Cr}_2\text{SO}_4$ ,  $\text{Na}_2\text{O}_2\text{Cr}_2$ ,  $\text{Na}_2\text{CrO}_4$ . Name the compounds. Write the symbols of the corresponding compounds of aluminum as far as they exist.

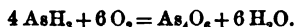
12. What is the action of heat on the ammonium compounds? Illustrate by  $\text{NH}_4\text{Cl}$ ,  $(\text{NH}_4)_2\text{SO}_4$ ,  $(\text{NH}_4)\text{NO}_3$ , but make also a general statement.

September, 1884.

1. A cube of crystallized  $\text{Na}_2\text{CO}_3 + 10\text{H}_2\text{O}$  (sp. gr. = 1.45) measures 6 cm. each way. How much space would the water of crystallization occupy in the liquid condition? How much space would the gaseous  $\text{CO}_2$  which might be obtained from it occupy under standard conditions?



2. How much oxygen by bulk would be required to burn 10 cc. of  $\text{AsH}_3$ ? Solve in the shortest manner possible.



3. Could you calculate the specific gravity of a liquid obtained by mixing 100 cc. of water with 100 cc. of pure sulphuric acid? If not, explain.

4. How could you prove that common and red phosphorus are only allotropic modifications of the same substance?

5. Describe the manufacture of caustic soda by the common process, starting with the materials that occur in nature, and indicating each step. Write equations.

6. Explain the difference between fractional distillation and fractional condensation. What distinction is usually made between sublimation and distillation? Illustrate by examples.

7. The specific gravity of air referred to hydrogen is 14.42. How does this show that air is a mixture and not a compound of the symbol  $\text{N}_4\text{O}$ ? What other reasons have we for regarding air as a mixture and not a chemical compound?

8. When nitric acid acts as an oxidizing agent, what happens to the nitric acid? Answer fully, and illustrate by several examples.

9. On what does the use of sulphuric acid as a drying agent depend? Why could it not be used to dry ammonia gas? Why could not quicklime be used to dry  $\text{HCl}$  gas?

10. Describe briefly the preparation of the following substances: carbonic oxide, nitrous oxide, chlorhydric acid.

11. What is iodo-starch paper, and for what used?

12. How much phosphorus by weight is contained in 10 litres of  $\text{PH}_3$  gas? How much space would this amount of P occupy in the gaseous state? How much in the solid state (sp. gr. = 1.83)?

### May, 1885.

1. Define specific gravity. Illustrate by examples.

2. Define allotropism. Illustrate by examples.

3. From what and how is ammonia water made? What is formed when ammonia and hydrochloric acid gases come together?

4. On what does the use of  $\text{H}_2\text{SO}_4$  as a drying agent depend? Why would it not be used to dry ammonia gas? Why would not quicklime be used to dry chlorine?

5. Explain the use of iodo-starch paper in testing for ozone? What other substance would affect the paper in the same way?

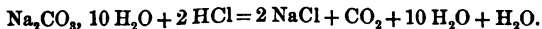
6. How purify  $\text{N}_2\text{O}$  completely from any NO with which it might be mixed? How purify CO from an admixture of  $\text{CO}_2$ ?

7. Give three different methods by which crystals may be formed. Illustrate by examples.

8. The symbol of a certain compound is  $\text{SnC}_4\text{H}_{10}\text{Br}_2$ . How much will one litre of its vapor weigh at  $273^\circ$  and 760 mm. pressure?

9. Could you calculate the specific gravity of a liquid obtained by mixing 100 cc. of water with 100 cc. of pure  $\text{H}_2\text{SO}_4$  if you knew the specific gravity of pure  $\text{H}_2\text{SO}_4$ ? If not, why not? What else do you think must be known?

10. A cube of crystallized  $\text{Na}_2\text{CO}_3 + 10 \text{H}_2\text{O}$  (sp. gr. = 1.45) measures 6 cm. each way. How much space would the water of crystallization occupy in the liquid condition? How much space would the gaseous  $\text{CO}_2$  which might be obtained from it occupy under standard conditions?



11. Fill the blanks below, and deduce the approximate atomic weight of chlorine.

| COMPOUNDS OF<br>CHLORINE. | OBSERVED<br>V. D. | M. W. | PER CENT OF<br>Cl IN<br>SUBSTANCE. | WEIGHT OF<br>Cl IN<br>MOLECULE. |
|---------------------------|-------------------|-------|------------------------------------|---------------------------------|
| Ethyl chloride . . . .    | 32.02             | —     | 55.                                | —                               |
| Boric chloride . . . .    | 56.85             | —     | 90.6                               | —                               |
| Phosgene gas . . . .      | 49.06             | —     | 71.7                               | —                               |
| Aluminic chloride . . .   | 134.8             | —     | 80.3                               | —                               |

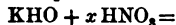
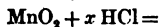
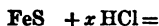
**May, 1886.**

1. What is ozone? How does it differ chemically and physically from oxygen? How may it be formed, and how destroyed?

2. Tell what you can of the chemical and physical properties of bromine; with what other elements is it grouped?

3. Define the term "anhydride," and illustrate fully by the two familiar oxides of sulphur.

4. Supply  $x$  in the following equation, and complete the right-hand members:—



5. Explain fully why  $\text{NaHSO}_4$  is called acid sulphate of soda.

6. How could you purify  $\text{N}_2\text{O}$  completely from any  $\text{NO}$  with which it might be mixed? How purify  $\text{CO}$  from an admixture of  $\text{CO}_2$ ?

7. What do we mean when we say the molecular weight of phosgene gas is 99?

8. What would be the weight in kilogrammes of one cubic metre of  $\text{H}_2\text{SO}_4$  (sp. gr. = 1.84)?

**September, 1887.**

1. Given an alloy of mercury, silver, and copper. Devise a method of obtaining each metal by itself.

2. Give the simplest method of testing impure  $\text{Na}_2\text{CO}_3$  for the presence of  $\text{Na}_2\text{SO}_4$ ; impure  $\text{CuSO}_4$  for  $\text{FeSO}_4$ ; impure  $\text{NH}_4\text{Cl}$  for  $\text{NH}_4\text{NO}_3$ .



3. State what change will take place when  $\text{Na}_2\text{SO}_4$  is heated with C; when  $\text{Al}_2(\text{SO}_4)_3$  is heated with  $\text{KNO}_3$ ; when  $\text{MnO}_2$  is heated with  $\text{HCl}$ ; when  $\text{Al}_2(\text{SO}_4)_3$  is heated with  $\text{Na}_2\text{CO}_3$ .

4. Explain the use of  $\text{HNO}_3$  in the manufacture of  $\text{H}_2\text{SO}_4$ .

5. Tell briefly how to prepare and all you have learned about  $\text{AsH}_3$ .

6. What do you understand by a basic salt? Illustrate by examples.

7. Name the following compounds and write their graphic symbols:  $\text{K}_2\text{Cr}_2\text{O}_7$ ;  $\text{BaSO}_4$ ;  $\text{SbOCl}$ ;  $\text{Ag}_3\text{SbS}_4$ .

8. What is the action of heat on the following:  $\text{NH}_4\text{Cl}$ ;  $\text{NH}_4\text{NO}_3$ ;  $(\text{NH}_4)_2\text{SO}_4$ .

9. How many litres of  $\text{SO}_2$  gas and liquid sulphuric acid (sp. gr. = 1.84) can be made from 10 kilos of sulphur?

10. Write the symbol of a molecule of chlorine; mercury; phosphorus. State clearly your reason for your belief in each case.



## SEMI-ANNUAL EXAMINATION PAPERS.



February, 1867.

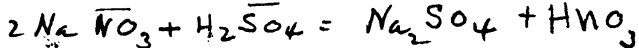
1. In 100 parts by weight of nitric acid, how many parts of hydrogen, nitrogen, and oxygen are there? Write out the calculation in full.

2. Describe briefly the common method of manufacturing sulphuric acid.

3. Explain "allotropy," "dimorphism," and the "law of multiple proportions."

4. Write the names and formulæ, and state briefly the more important physical and chemical properties of the compounds of hydrogen with O, Cl, N, S, Br, I, and Fl.

5. For each of the compounds mentioned in question 4, state the number of volumes of its elements in the gaseous condition which must be taken in order to obtain the normal volume product. State also the



# EXAMINATION PAPERS.

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amount of condensation which occurs in each particular instance, as the elements combine.

6. Describe the means of obtaining nitric acid, and state the quantities of sulphuric acid ( $\text{H}_2\text{SO}_4$ ) and of nitrate of sodium ( $\text{NaNO}_3$ ) which must be taken in order to obtain 100 pounds of nitric acid (the atom of Na weighs 23).

7. Describe the preparation of chlorhydric acid gas, and state its composition, specific gravity and combining weight.

8. What is the composition of water in 100 parts? State in words, and describe by symbols the reaction which occurs when iron turnings are treated with chlorhydric acid.

9. How much heavier than hydrogen are the following gases and vapors: ammonia, nitric oxide, steam, nitrogen, and sulphurous acid?

10. From what sources are bromine, iodine, and sulphur derived? How are they prepared and collected?

11. What is the difference between a chemical compound and a mechanical mixture?

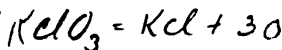
12. Which of the chemical elements are allied to chlorine; to oxygen; to sulphur; and in what particulars may this alliance be observed?

13. Write out the empirical and rational formulæ of the following substances: nitrate of ammonium, nitrate of lead, sulphate of sodium, chloride of potassium, iodide of sodium, and sulphite of calcium.

14. Explain by symbols the reaction which takes place when oxygen gas is prepared by heating a mixture of binoxide of manganese and chlorate of potassium.

15. How is phosphorus prepared in its ordinary and in its allotropic form?

16. How much chlorate of potassium is required to produce 4 litres of oxygen measured at  $0^\circ$  and under a pressure of 76 cm.? (One litre of hydrogen at the same temperature and pressure weighs .09 gm. The weight of an atom of K = 39, of an atom of Cl = 35.5.) Give such numerical details as will show the method of calculation.



January, 1870.

1. What is the weight of a molecule of chloride of carbon? of chloride of boron?

2. State in words and describe by words the reaction which occurs when metallic copper is heated with sulphuric acid.

3. Write the formulæ of normal silicate of sodium, bisilicate of sodium, disilicate of sodium, sulpho-carbonic acid, quicklime, common salt, chloride of zinc, oxide of sodium, oxide of lead, and sulphantimoniate of sodium.

4. In preparing nitric acid, how much oil of vitriol and how much saltpetre must be taken in order to obtain a pound of nitric acid?

5. By experiment we find the specific gravity of ammonia gas to be 8.02; how can we apply this observation in determining the composition of ammonia?

6. What gaseous compounds of hydrogen can be readily dissociated by heat?

7. How can we determine the composition of sulphurous acid by the way of synthesis?

8. Write the symbols of all the oxygen acids in the "nitrogen group of elements."

9. How many pounds of nitrogen are there in 100 pounds of saltpetre?

10. Define the meaning of the terms "isomorphism," "dimorphism," "allotropism," and "isomerism."

11. Name four important uses of carbon.

12. How is phosphorus prepared?

13. How would you detect the presence of chlorine in any mixture?

14. How is nitrous oxide prepared? Describe the matter by symbols.

15. How would you prove beyond cavil that carbon is given out during the respiration of animals?

16. How much air is necessary to burn completely 10 grms. of pure carbon?

17. In what proportions should chlorhydric acid and black oxide of manganese be mixed to generate chlorine?

18. What is the chemical explanation of the action of chlorine in bleaching?

19. Describe the reactions in a candle flame.

20. How would you determine the atomic weight of silicon?

January, 1871.

1. What is the weight of a molecule of each of the following gases:  $N_2O$ ,  $HCl$ ,  $PH_3$ ,  $O$ ,  $NH_3$ ? What is the specific gravity of each gas?

2. The composition of carbonic acid being known, how can we determine the composition of carbonic oxide?

3. Supply the other side of this equation:—



What other substances could take the place of the copper in bringing about a similar reaction?

4. Define an empirical formula; a dualistic formula; a rational formula; a typical formula. Illustrate by writing the various formulæ for caustic potash.

5. Write the reaction for producing oxygen from chlorate of potassium. How many litres of oxygen ought we to obtain from 100 kilograms of chlorate of potassium, the oxygen being measured under the conditions of temperature and pressure under which a litre of hydrogen weighs .09 gm.?

6. How much air by weight is necessary to burn one gramme of lamp-black?

7. Describe the preparation of nitric acid.

8. Describe the preparation of ammonia water, and state the original source of the substances employed.

9. Which of the following gases could be easily collected over water:  $HCl$ ,  $NH_3$ ,  $Cl$ ,  $CO$ ,  $SO_2$ ,  $NO$ ,  $CO_2$ .

10. Define allotropism, isomerism, unit of heat, nascent state.

11. Name the natural sources of P, I, S, As.

12. On what property does the use of sulphuric acid in drying tubes depend?

13. State the difference between ordinary and red phosphorus. How may one variety be converted into the other?

14. From the formula for sulphuric acid derive that of sulphate of sodium; that of sulphate of calcium. Explain the difference between the two formulæ.

15. What elements are classed with chlorine? Which with oxygen? Which with nitrogen? State the resemblances and the dissimilarities among the members of the chlorine group.

16. For what practical purposes are the following substances prepared, and on what properties does their use in each case depend:  $\text{H}_2\text{SO}_4$ ,  $\text{SO}_2$ ,  $\text{Cl}$ ,  $\text{NH}_4\text{NO}_3$ ?

17. State various methods for obtaining a substance in crystals.

18. What gases are readily dissociated?

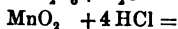
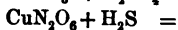
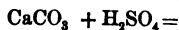
19. How many volumes of each of the component elementary gases are contained in two volumes of ammonia gas; of phosphuretted hydrogen; of dry steam; of sulphurous acid?

20. The specific gravity of the vapor of alcohol referred to hydrogen being 23, how shall we decide whether the correct formula is  $\text{C}_2\text{H}_6\text{O}$ ,  $\text{C}_4\text{H}_{12}\text{O}_2$ , or  $\text{C}_8\text{H}_{24}\text{O}_4$ , all of these formulæ answering equally well to the percentage composition?

### January, 1872.

1. Write the formula of nitric acid; of nitrate of lead; of nitrate of sodium; of nitrate of ammonium.

2. Supply the other side of the following equations:—



3. What is the molecular weight of each of the following substances: nitrogen, carbonic acid, ammonia, caustic soda, nitrate of potassium, phosphorus?

4. What is the natural source of the following substances: phosphorus, nitric acid, chlorine, antimony?

5. Define "acid," "base," "anhydride"; also terms "isomorphous," "isomeric," and "atomic weight."

6. Sulphuric acid is *bibasic*. Explain what is meant by the term, and illustrate by examples.

7. How may we prepare in the laboratory ammonia water, sulphurous acid, pure water?

8. What is the specific gravity referred to hydrogen of each of the following gases:  $\text{CO}$ ,  $\text{SO}_2$ ,  $\text{NO}$ ,  $\text{H}_2\text{O}$ ,  $\text{CH}_4$ ?

9. How much oxygen by weight would be required for the complete combustion of 10 litres of marsh gas ( $\text{CH}_4$ ), the litre of hydrogen weighing .09 grms.

10. What is the chemical name of slaked lime, litharge, iron rust, common salt, marsh gas?

11. What is *aqua regia*? What action does it have on gold and platinum, and on what does this action depend?

12. What elements are grouped with chlorine? What with oxygen? State some of the grounds on which the classification is based.

13. Define "product volume," and illustrate by at least four essentially different examples.

14. Define "allotropism," and give examples.

15. Explain what is meant by the term "combustion."

16. What happens to the following substances when subjected to heat: nitrate of ammonium, sulphuretted hydrogen, arseniuretted hydrogen?

17. We find by analysis that a certain volatile liquid is made up of carbon and hydrogen, and contains twice as many atoms of hydrogen as of carbon; we also find the vapor density of the compound to be 21. What is the formula of the molecule of the compound?

18. Give the argument by which the hypothesis that free hydrogen should be represented by the formula  $\text{H}-\text{H}$  is rendered probable.

19. How may the composition of carbonic oxide be determined, that of carbonic acid being known?

20. Describe a method for determining the volumetric composition of nitrous oxide ( $\text{N}_2\text{O}$ ).

### January, 1873.

1. Of what gases is air composed? In what proportion are the gases mixed? Describe Lavoisier's experiment to prove that air is made up as has been stated, and show that in the air the gases are mixed together, and are not in chemical combination.

2. Which of the elements already studied occur in the free state in nature?

3. Define "allotropism," and illustrate by two examples.

4. Describe, in general terms, the preparation of sulphuretted hydrogen, ammonia water, and sulphurous acid.

5. Define atom and molecule.

6. What is the law with reference to the molecular constitution of gaseous substances (law of Ampère)?

7. How many cubic cm. make a litre?

8. How much would a litre of oil of vitriol (sp. gr. = 1.83) weigh?

9. Sulphuretted hydrogen burns in air. Write the reaction.

10. Define "combustion" in its fullest sense.

11. What relation exists between vapor density and molecular weight of a chemical compound?

12. Define "specific gravity" and "atomic weight." In the case of what substances does the same number represent both specific gravity and molecular weight?

13. Express by an equation what takes place when fluoride of calcium ( $\text{CaF}_2$ ) is treated with sulphuric acid.

14. What is the nitrogen group? What resemblance and what dissimilarities exist among the members of this group?

15. How much sulphur is there in a litre of sulphuretted hydrogen? ( $\text{S} = 32$ ; suppose the litre of  $\text{H}$  to weigh .0896 grms.)

16. Write the symbol of the molecule of nitric acid, chlorhydric acid, caustic soda, phosphorus, oxygen, and mercury.

17. What is meant by an acid? Define the term in its most restricted and in its more general sense.

18. What properties of arsenic or of its compounds afford us the means of detecting its presence in a given substance?

19. Describe the manufacture of sulphuric acid on the large scale, stating the various reactions which occur.

#### January, 1874.

1. What relation exists between an acid and the corresponding salts? Illustrate by examples.

2. What is the diffusive power of a gas? How does this power vary in different gases?
3. How could you show that a candle flame is really a gas flame?
4. How could you obtain metallic arsenic from arsenious anhydride?
5. Give the various names for the compound  $H_2S$ .
6. Write the symbol of the molecule of chlorine; sulphuric acid; nitric acid; phosphorus; oxygen; arsenic.
7. Define an oxide.
8. Give a method practicable on a large scale for preparing oxygen; chlorine; carbon protoxide; nitric acid. Write reactions involved in each case.
9. How much (by measure) of ordinary muriatic acid containing 36 per cent of real  $HCl$  must be used to dissolve 26 grms. of pure calcium carbonate ( $CaCO_3$ )? How much  $CO_2$  (both by weight and measure) would be given off?
10. How would you remove the oxygen from a mixture of oxygen and nitrogen?

### January, 1878.

1. Tell how the following substances occur in nature, of what use they are in the arts, and what is the best solvent for each: Ag, Pb, Hg, Cu, and S.
2. Define the following terms and give examples: homologous series, compound radical, sublimation, distillation.
3. Describe the preparation of  $CO_2$ ,  $SO_2$ ,  $SO_3$ , and give the marked properties of each.
4. How could you convert  $BaCl_2$  in solution in water into  $BaSO_4$  insoluble in water and acids?
5. How much silver by weight could be obtained from 28.7 grms. of  $AgCl$ ?
6. If  $CO$  be burnt in oxygen, what are the relative bulks of the gases concerned in the action?  $2 CO + O_2 = 2 CO_2$ .
7. Let  $M$  be the symbol of a certain gaseous element: suppose that we know (1) that the "law of Ampère" is true; (2) that the molecule of the



chloride contains 2 atoms of the element M (call it  $M_2Cl_6$ ); (3) that from 2 volumes of the chloride in the state of vapor, we can set free  $\frac{2}{3}$  of a volume of M and 6 volumes of chlorine. Show how many atoms of M there would be in a molecule of the corresponding elementary substance.

8. Give the chemical name for each of the following substances, and the chemical symbols when possible: cinnabar, vermilion, horn silver, galena, oil of vitriol, white arsenic, verdigris, red lead, white lead, nitre.

9. How could you test most simply a green paper supposed to be colored by an arsenical pigment? Explain how you could determine with absolute certainty whether As was present.

10. What is the essential difference between the mercurous and mercuric compounds? How do cuprous and cupric oxide differ from each other in symbol and appearance?

### January, 1879.

1. Describe the preparation in the laboratory of the following substances:  $PH_3$ ,  $AsH_3$ ,  $NI_3$ , and give the chief characteristics of each.

2. If the symbol of certain chromates is as follows, what is the symbol of chromic acid:  $K_2CrO_4$ ,  $CaCrO_4$ ,  $ZnCrO_4$ ?

3. What is the weight of one litre of  $SnC_4H_{10}Br_2$  if one litre of H weighs .0896 grms.

4. When  $AsH_3$  burns, the reaction may be written:  $2 AsH_3 + 3 O_2 = As_2O_3 + 3 H_2O$ .

5. How many cubic centimetres of oxygen gas would be required to burn one-half a litre of  $AsH_3$ , and how much  $As_2O_3$  would be formed?

6. Show what the so-called Law of Ampère has to do with the last question.

7. State the various natural and artificial processes by which  $CO_2$  is produced, and why does the proportion of this gas in the atmosphere remain nearly uniform?

8. What is an *alcohol*? an *ether*? How is alcohol related to any member of the marsh gas series?

9. How much sulphur by weight would be required to make 10 kilogrammes of  $H_2SO_4$ , supposing there be no waste? If the sp. gr. of the  $H_2SO_4$  is 1.84, how many litres would the 10 kilogrammes measure?

## January, 1880.

1. What is a "safety tube"? Describe its operation by drawing a diagram, and recall some actual case in which its use is essential.
2. What is the most marked feature of the so-called non-metallic elements taken as a class?
3. In what proportion by volume must the following gases be mixed with air to have in each case the most explosive mixture possible: hydrogen, carbon protoxide, carbon bisulphide (as a gas), marsh gas? Write equations to represent as far as it is possible the chemical action that takes place.
4. Describe the Argand burner, and tell how we can show by experiment the use of the chimney. Why will not the same sort of a gas burner serve equally well for any illuminating gas?
5. Calculate the percentage composition of  $\text{SnC}_4\text{H}_{10}\text{Br}_2$ .
6. How many litres of chlorhydric gas could be obtained by treating with  $\text{H}_2\text{SO}_4$  a cube of rock salt ( $\text{NaCl}$ ) measuring 5.5 cm. each way?

## January, 1881.

1. How could you prove conclusively that the diamond, graphite, and charcoal are merely allotropic modifications of one and the same substance?
2. How many cubic centimetres of oxygen would it take to burn 75 cc. of benzol vapor, and how much space would the  $\text{CO}_2$  formed occupy? How much would the water formed weigh?  $2 \text{ C}_6\text{H}_6 + 15 \text{ O}_2 = 12 \text{ CO}_2 + 6 \text{ H}_2\text{O}$ .
3. The specific gravity of air referred to hydrogen is 14.42. How does this show that air is not a compound having a symbol  $\text{N}_x\text{O}_y$ ? What other reasons have we for regarding air as a mechanical mixture and not as a chemical compound?
4. If you had a mixture of carbonic anhydride and nitrogen, how could you remove the former completely so as to leave the latter pure?
5. How much phosphorus *by weight* is contained in 10 litres of  $\text{PH}_3$  (measured under standard conditions)? How much space would this amount of phosphorus occupy in the gaseous condition? How much in the solid condition? (A litre of H weighs .0896 grms. The specific gravity of common phosphorus is 1.83. Atomic weight of P = 31.)

January, 1883.

1. Describe the various kinds of distillation, and illustrate each by an example.

2. How is hydrogen sulphide prepared? Tell all you can of its properties. For what is it used in the laboratory?

3. The empirical formula of hypophosphorous acid is  $\text{H}_3\text{O}_2\text{P}$ , and the acid is *mono*-basic. Write the symbols and give the names of the corresponding salts of  $\text{Na}'$  and  $\text{Ba}''$ .

4. At a temperature of  $450^\circ$  the vapor density of iodine is 126.8; at  $1350^\circ$  the vapor density is 63.4. Write the symbol of the molecule of iodine at each of the two temperatures.

5. Calculate the percentage composition by weight of the sulphochloride of phosphorus,  $\text{PSCl}_3$ .

6. Define allotropism, and illustrate fully by the example of phosphorus.

7. Suppose that you have three white powders, soluble in water, one of them being a chloride, one a bromide, and one an iodide. How can you tell which is which?

8. Give three distinct methods of forming salts, and illustrate each method by an example.

9. Define the term "atom." What is a microcrith? Under what conditions is it true that a litre of hydrogen weighs .0896 grms.?

10. Write out in words the volumetric interpretation of  $\text{HgC}_4\text{H}_{10}$  and of  $\text{AsI}_3$  as far as it is possible to do so. (These compounds can be changed to gases.)

11. How many cubic centimetres of dilute nitric acid (sp. gr. = 1.228) containing 36.28 per cent of real  $\text{HNO}_3$  will be required to dissolve a strip of copper (sp. gr. = 8.8)?

10.806 cm. long, 4 cm. wide, and .5 mm. thick?



12. How many cubic centimetres of NO will be formed under the circumstances of the previous question?

January, 1884.

1. When  $\text{HNO}_3$  acts as an oxidizing agent, what happens to the  $\text{HNO}_3$ ? Answer fully, and illustrate by several examples.

2. On what does the use of  $\text{H}_2\text{SO}_4$  as a drying agent depend? Could it not be used to dry  $\text{NH}_3$  gas? Why could not quicklime be used to dry  $\text{HCl}$  gas?

3. Give two different methods of preparing  $\text{SO}_2$ . What is the common test for  $\text{H}_2\text{SO}_4$ ?

4. What happens to iron pyrites when heated out of contact with air? When heated in the presence of much air?

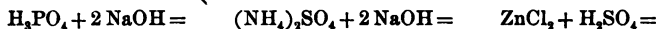
5. Explain the use of iodo-starch paper in testing for ozone. What other substances would affect the test paper similarly?

6. How could you purify  $\text{N}_2\text{O}$  completely from any  $\text{NO}$  with which it might be mixed?

7. How purify  $\text{CO}$  from an admixture of  $\text{CO}_2$ ?

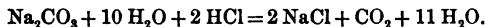
8. What happens when charcoal is exposed to an atmosphere of  $\text{H}_2\text{S}$ ?

9. Complete the following equations:—



10. Could you calculate the specific gravity of a liquid obtained by mixing 100 cc.  $\text{H}_2\text{O}$  with 100 cc. pure  $\text{H}_2\text{SO}_4$ , if you know the specific gravity of pure  $\text{H}_2\text{SO}_4$ ; if not, why not? What else do you think you would have to know?

11. A cube of  $\text{Na}_2\text{CO}_3 \cdot 10 \text{H}_2\text{O}$ , specific gravity 1.45, measures 6 cm. each way. How much space would be occupied by the water of crystallization in a liquid condition? How much space would the gaseous  $\text{CO}_2$  which might be obtained from it occupy under standard conditions?



12. Fill the blanks below, and tell the approximate weight of chlorine.

|                          | V. D.  | M. D. | PER CENT CL. | WT. CL. |
|--------------------------|--------|-------|--------------|---------|
| Ethylic chloride . . . . | 32.02  | —     | 55           | —       |
| Boric chloride . . . . . | 56.85  | —     | 90.6         | —       |
| Phosgen gas . . . . .    | 49.06  | —     | 71.7         | —       |
| Aluminic chloride . . .  | 134.80 | —     | 80.3         | —       |

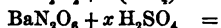
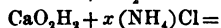
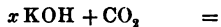
January, 1885.

1. Describe the preparation in the laboratory of fluorhydric acid and of hydrogen sulphide. State the materials employed; give a sketch of the apparatus, and give in each case some *test* by which you can satisfy yourself that you are really getting the desired substance.

2. Tell all that you have learned in the laboratory of the properties of the substance iodine.

3. If you had a supposed mixture of nitrogen and nitric oxide (NO), how could you satisfy yourself whether the latter gas was present or not? What is the common test for CO<sub>2</sub>?

4. Supply the proper number in the place of  $x$  and complete each of these equations:—

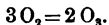


5. What is a crith? a microcrith? What is the difference between a chloride, a chlorite, and a chlorate?

6. What, according to present theoretical views, is the difference between elementary and compound substances? What is the difference between a rational and an empirical symbol?

7. When nitric acid acts as an oxidizing agent, what visible evidence of the fact do we usually have?

8. If it were possible to convert one litre of oxygen completely into ozone, how much space would the ozone occupy, the temperature and pressure being unchanged?



9. How many cubic centimetres of marble (CaCO<sub>3</sub>, sp. gr. = 2.72) must be dissolved in HCl in order to give 5 litres of CO<sub>2</sub>? Draw the figure of a cube or of a parallelopiped to show the approximate size of the necessary lump.



10. Calculate the percentage composition by weight of zinc methide (ZnC<sub>2</sub>H<sub>6</sub>), and tell what would be the weight of one litre of the substance as gas at a temperature of 273° and under standard pressure.

## January, 1886.

1. Give three methods of obtaining a substance in the form of crystals, and illustrate by examples from your own experience.

2. How is hydrogen generally prepared in the laboratory? Give two methods of preparing oxygen.

3. Tell all you have observed in the destructive distillation of wood.

4. What is bone coal? Describe briefly the experiments you have performed with this substance; also those with bone-black.

5. Write out as far as it is possible the atomic, gravimetric, and volumetric composition of  $\text{NO}_2$ ,  $\text{PH}_3$ ,  $\text{CO}_2$ .

6. What is the law of multiple proportions? Illustrate by an example.

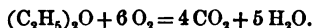
7. What do we mean when we say the molecular weight of phosgen gas is 99?

8. If the symbol of ferrate of potassium is  $\text{K}_2\text{FeO}_4$ , what is the symbol of ferric acid?

9. What would be the weight in kilogrammes of 1 cc. of  $\text{H}_2\text{SO}_4$  (sp. gr. 1.84)?

10. Calculate the percentage composition by weight of ether  $(\text{C}_2\text{H}_5)_2\text{O}$ .

11. How much oxygen by weight will be required to burn 1 cc. of ether (sp. gr. = .730)?



12. What is the vapor density of ether? If 1 cc. of liquid ether was converted into a gas, how much space would the gas occupy at  $273^\circ$  and 760 mm. pressure?

## January, 1887.

1. Tell briefly how to prepare  $\text{HF}$ ,  $\text{H}_2\text{S}$ , liquid  $\text{NO}_2$ ; and give some test by which you can satisfy yourself that you are really getting the desired substance.

2. Prove that the molecule of hydrogen contains at least two atoms. Can it be proved by one reaction?

3. Write out, so far as is possible to do so, the atomic, gravimetric, and volumetric composition of  $\text{C}_2\text{H}_6$ ,  $\text{Pl}_3$ , and  $\text{HgCl}_2$ .

4. The specific gravity of solid  $\text{As}_2\text{O}_3$  is 3.75. What volume of arsenic vapor could be obtained from 23.628 cc. of this substance? What space would the arsenic occupy in the solid state (sp. gr. = 5.6)?

5. Name and tell how to distinguish between  $\text{BaSO}_4$ ,  $\text{NaNO}_3$ ,  $\text{PbN}_2\text{O}_6$ , and  $\text{NaCl}$ .

6. Supply  $x$  and complete the following:—

- (a)  $\text{NH}_4\text{NO}_3$  heated =
- (b)  $(\text{NH}_4)_2\text{SO}_4 + x \text{KOH} =$
- (c)  $x \text{NH}_4\text{Cl} + \text{H}_2\text{SO}_4 =$
- (d)  $x \text{Cu} + x \text{HNO}_3 =$
- (e)  $x \text{Cu} + \text{H}_2\text{SO}_4 =$
- (f)  $x \text{Zn} + \text{H}_2\text{SO}_4 =$

Explain reactions (d), (e), and (f).

7. Define the terms "acid," "allotropism," "nascent state," "sublimation," and illustrate by examples. Distinguish clearly between a sulphide, sulphate, and sulphite.

8. What happens when paper dipped in a mixture of starch and potassium iodide solution is inserted (1) into a bottle containing bits of marble and sulphuric acid; (2) into "ozonized air"; (3) into a tube containing a few crystals of iodine; (4) into a bottle containing bleaching powder; (5) into a tube containing a few drops of bromine?

9. In how many ways may crystals be formed? Illustrate by examples.

### January, 1888.

1. Given the percentage composition of nitrobenzol: C, 58.53; H, 4.07; N, 11.39; O, 26.01. Required the simplest symbol possible.

2. How many cubic centimetres of sulphuric acid, specific gravity 1.4, must be used to make 50 litres of  $\text{H}_2\text{S}$ ?



Sulphuric acid of this specific gravity is fifty per cent pure.

3. Write the symbols of the following compounds: silicate of soda, phosphate of magnesia and ammonia, neutral phosphite of magnesia, nitrous oxide, nitric anhydride, molybdate of ammonia.

4. Describe briefly the manufacture of sulphuric acid.

5. Make ammonia, using  $\text{NH}_4\text{NO}_3$ ; chlorine, using  $\text{NaCl}$ . Answer by reactions only.

6. How could  $\text{Na}_2\text{SO}_4$  be tested for  $\text{BaSO}_4$ ?  
How could  $\text{NH}_4\text{NO}_3$  be tested for a chloride soluble in water
7. How could you make  $\text{FeS}$ ,  $\text{CuCl}_2$ ,  $\text{ZnCl}_2$ ,  $\text{HCl}$ ,  $\text{N}_2\text{O}$ ,  $\text{Pb}(\text{NO}_3)_2$ ,  $\text{NaCl}$ ?
8. What is bleaching powder? Write the reaction of sulphuric acid on it.
9. How would you dry ammonia, chlorine, sulphurous oxide, and hydrochloric acid gases?
10. What is the simplest way of detecting  $\text{NO}$  in  $\text{N}_2\text{O}$  gas? What are the simplest chemical tests for  $\text{NH}_3$ ,  $\text{H}_2\text{S}$ , and ozone?
11. How does vapor density aid us in determining molecular weights? Explain why vapor density is not exactly one-half the molecular weight. Do you know whether the molecules of substances are the same in the gaseous and solid state? Are the molecules of a gas necessarily the same at different temperatures? If not, mention any case or cases you know where they are different, and state how it can be proved.

DATA. Silicon (Si) has a valence of 4. Phosphorus (P) has a valence of 3 and 5. Magnesium (Mg) has a valence of 2. Molybdenum (Mo) has a valence of 6.



## INTERMEDIATE EXAMINATION PAPERS.



November, 1884.

1. Give law of definite and multiple proportions. Illustrate by examples.
2. Tell what we mean by a theory. Illustrate by examples.
3. How prepare liquid  $\text{NO}_2$ ?
4. Give two ways of getting  $\text{N}$  from air.
5. In what respects do  $\text{O}$  and  $\text{N}_2\text{O}$  resemble each other, and how tell them apart?
6. Tell all you notice when you heat  $\text{KClO}_3$  in a tube.
7. What does the symbol  $\text{H}_2\text{O}$  tell us of the composition of  $\text{H}_2\text{O}$  by weight?



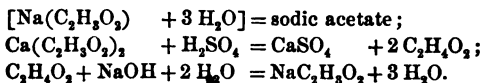
8. How prepare  $N_2O$ ?
  9. Explain by diagram the construction of a Bunsen lamp.
  10. Tell exactly what you mean when you say the atomic weight of iron is 56.
  11. Name two gases which are extremely soluble in water.
  12. Name two gases which are distinctly colored.
  13. Complete these equations :—
 
$$\begin{array}{rcl} NaNO_3 + H_2SO_4 & = & \\ NaOH + HCl & = & \\ Mg & + 2HCl & = \end{array}$$
  14. Tell what *three* conditions every properly written equation must satisfy.
  15. In what three ways may chemical symbols be interpreted? Illustrate by  $HCl$  and  $HgO$ .
  16. Tell all you observe when starch is heated with  $HNO_3$ .
  17. How much copper ( $Cu$ ) would be required to furnish 2 litres of  $NO$  gas?
 
$$3 Cu + 8 HNO_3 = 3 CuN_2O_6 + 4 H_2O + 2 NO.$$
- If the specific gravity of  $Cu$  is 8.8, how much space would the copper occupy?

### March, 1885.

1. Give three general methods by which we may determine the electrochemical relations of the elements, and explain in each case the use of the terms "positive" and "negative."
2. What advantages does the use of the spectroscope have over the "flame test"?
3. How could you obtain pure silver from a silver coin?
4. What are the advantages of a many prism spectroscope over one of a single prism?
5. To what general test do all the ammonium compounds answer?
6. Tell all you know about  $AgCl$ .
7. How much  $K_2CrO_4$  could be made from 762 grms. of  $Cr_2O_3$ ?

8. What are some of the tests for lead?
9. What happens when a strip of zinc is put in a solution of  $\text{CuSO}_4$ ?
10. What is chrome alum? What is an alum? What is copperas?
11. Explain the use of cobalt chloride solution in "invisible" or "sympathetic" ink.
12. What is soda ash? Baking soda? Washing soda? Caustic soda? Give symbols.
13. When you add a solution of soap to  $\text{NaCl}$  solution, a white precipitate falls. When a solution of soap is added to a solution of  $\text{CaCl}_2$ , a white precipitate falls. What are the two precipitates?
14. How could you test a substance supposed to be boric acid?
15. How much crystallized boric acid ( $\text{H}_3\text{BO}_3$ ) can be made from 100 grms. of crystallized borax ( $\text{Na}_2\text{B}_4\text{O}_7 \cdot 10 \text{H}_2\text{O}$ )?
16. What happens when quicklime is slaked?
17. Explain by clear sketches the oxidizing and reducing flame of the blowpipe.
18. Explain the use of  $\text{AgNO}_3$  in an indelible ink.
19. What is cryolite, where is it found, and what is it good for?
20. How is the so-called ammonium amalgam prepared? Describe its appearance, and tell what it is supposed by some to be.
21. What is an hydroxide? Write the symbol of the hydroxide of  $\text{Na}^{\text{I}}$ ,  $\text{Ca}^{\text{II}}$ ,  $\text{Bi}^{\text{III}}$ ,  $(\text{Fe}_2)^{\text{IV}}$ .
22. Explain what happens when an electric current passes through a very dilute solution of  $\text{H}_2\text{SO}_4$ .
23. What is a supersaturated solution?
24. What is the symbol of marsh gas? How and where does it occur in nature, and how is it prepared in the laboratory?
25. Why does sodium burn on ice?
26. If you add water to an alcoholic solution of iodine, a precipitate is produced. What is the precipitate? Why does it come down?
27. What is water glass? What is the precipitate formed when  $\text{HCl}$  is added to a solution of water glass?
28. How much acetic acid could you get by distilling 158 grms. of

calcium acetate with  $\text{H}_2\text{SO}_4$ , and how much crystallized sodic acetate could you make from it?



29. What have you learned about the oxides of lead?
30. Which of the acids is the best solvent for lead? Write equation.
31. How are the metals Na and K obtained in the arts?
32. What have you learned about the oxide and hydroxide of aluminum,  $\text{Al}_2\text{O}_3$  and  $\text{Al}_2\text{O}_3\text{H}_6$ ?
33. How does carbonate of calcium occur in nature?
34. How much  $\text{Fe}_2\text{O}_3\text{H}_6$  can be made from 76 grms. of  $\text{FeSO}_4$ ? Equations.
35. What is the difference of light coming from a heated solid and that from a heated vapor, and how is the difference shown?

#### April, 1886.

1. What happens when nitric acid is added to a hot solution of a ferrous salt?
2. What happens when "nascent" hydrogen acts on a solution of ferric chloride?
3. How prepare "carmin lake"?
4. Give a test for the presence of manganese.
5. Why is  $\text{CaSO}_4$  a bad thing to have in "boiler water"?
6. How is bleaching powder made? How obtain oxygen from it?
7. What happens when caustic soda is added to a mercuric salt solution?
8. How distinguish between a soluble mercurous and mercuric salt?
9. What solvent do you know for mercury?
10. What is the blowpipe test for cobalt?
11. What do we mean when we say that zinc sometimes acts as a negative element and sometimes as a positive element? Illustrate fully by examples.

12. Give two methods by which we may obtain pure silver from an alloy of silver and copper.
13. How prepare antimonureted hydrogen? What are its properties?
14. How is silver obtained from an alloy of silver and lead?
15. What three oxides of lead? Give name and symbol.
16. How is metallic potassium prepared?
17. What happens to potassium tartrate when subjected to destructive distillation?
18. What is ammonium amalgam?
19. What is meant by the "hardness" of water?
20. Give three methods by which you may determine the electrochemical relation of the elements. Illustrate by examples of each.
21. What takes place when ammonium chloride and carbonate of calcium are heated together?
22. What do we mean by a deliquescent substance?
23. What happens when sodium is thrown upon water?
24. What do you know of the appearance and solubility of  $\text{PbCl}_2$ ?
25. How is caustic soda obtained from the carbonate?
26. What is an hydroxide? Give two examples.
27. Explain the Leblanc process for making sodium carbonate.

### February, 1887.

1. Knowing the symbol of certain chlorides,  $\text{NaCl}$ ,  $\text{SbCl}_3$ , and  $\text{CaCl}_2$ , and the symbol of propionic acid  $\text{C}_2\text{H}_5\text{CO}_2\text{H}$ , write the symbol of the propionates of Na, Sb, and Ca. Write the symbol of propionic anhydride.
2. What do we mean when we say the molecular weight of di-methyl-di-phenylamine is 183?
3. What difference exists between the soaps and fats? How would you detect the presence of silica in a mineral?
4. From what source is borax obtained?
5. From a mixture of 998 cc. of oxygen and ozone 1000 cc. of oxygen was obtained. How much oxygen was in the mixture ( $2\text{O}_3 = 3\text{O}_2$ )?

**November and December, 1887.**

1. Correct where necessary : a molecule of water, a molecule of sugar, an atom of mercuric oxide, an atom of nitrogen.

2. Describe the blast lamp.

3. Give three ways of preparing H from water. Tell what becomes of the O in each case.

4. Define molecular weight. Atomic weight.

5. Describe the Bunsen burner.

6. What gases have you had which will support combustion? What ones extinguish combustion?

7. What happens when you heat mercuric oxide? Tell all you observed.

8. Derive simplest formula of a compound of the following percentage composition :—

$$C = 39.13; H = 8.69; O = 52.17.$$

9. Define a molecule; an atom.

10. State your reason for considering air a mixture of gases.

11. What are the chemical properties of  $N_2O$  and of H?

12. Give three ways of making oxygen gas.

13. What is the specific gravity of hydrogen gas referred to water? A litre of H weighs .0896 grms.

14. We have a mixture of  $N_2O$  and O. Separate (1) by mechanical means; (2) by chemical means. State why chemical and why mechanical.

15. What is Avogadro's law? How does this law enable us to calculate molecular weights?

16. What is the difference between the burning of H and exploding H.

17. Mention five instances where you have prepared salts. Reactions only.

18. Give the reactions for preparing nitric acid and chlorhydric acids. How were the acids collected?

19. What is *aqua regia*? Why does it dissolve gold?

20. Given two white powders, one sodium chloride and one ammonium chloride. How identify them?

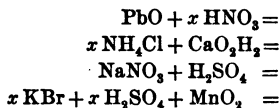
21. How test for ammonia gas; chlorine; bromine; oxygen?

22. What is an "oxidizing agent"?

23. How many litres of oxygen will be required, and how many litres of  $\text{CO}_2$  will be produced by burning one kilo of carbon ( $\text{C} + \text{O}_2 = \text{CO}_2$ )?

24. Select the bases in the following:  $\text{NH}_3$ ;  $\text{NaOH}$ ;  $\text{H}_2\text{SO}_4$ ;  $\text{HCl}$ ;  $\text{CuO}$ ;  $\text{CaO}_2\text{H}_2$ ;  $\text{NaCl}$ .

25. Finish:—



26. Write the reaction when lead nitrate is heated; when ammonium nitrate is heated.

27. What is your reason for saying the molecule of hydrogen has at least two atoms?

28. How distinguish  $\text{Na}_2\text{SO}_4$  from  $(\text{NH}_4)_2\text{SO}_4$ ?

29. The vapor density of P at  $x^\circ$  is 62; at  $y^\circ$  it is 31. Write the symbol of a molecule in each case.

30. How is bleaching powder made? How bleach with it?

31. Given two powders,  $\text{KI}$  and  $\text{KNO}_3$ . How identify them?

### February, 1888.

1. Give the chemical name for water glass; sal soda; sal ammoniac; Glauber's salt.

2. Write the reaction of  $\text{CO}_2$  on heated potassium. Under what conditions could this reaction be reversed?

3. What would be the simplest and cheapest method of obtaining  $\text{KNO}_3$  from  $\text{KNO}_3$  adulterated with one-half per cent of  $\text{NaCl}$ ?

3. Mention any process of manufacture where success depends on the comparative insolubility of the product sought.

4. What is formed when Na burns on charcoal before the blowpipe?

5. How is sodium manufactured?

6. Give the law of multiple proportions. Illustrate by examples.
7. When  $\text{NH}_4\text{Cl}$  is heated in a test tube, what takes place? What is dissociation?
8. What is "water of crystallization"? Mention two salts that have and two that have no water of crystallization.
9. How obtain  $\text{KOH}$  from  $\text{K}_2\text{CO}_3$ ?
10. How recognize  $\text{Na}_2\text{SO}_4$ ;  $\text{NaNO}_3$ ;  $\text{Na}_2\text{CO}_3$ ;  $\text{NaCl}$ ;  $\text{Na}_4\text{SiO}_4$ ?
11. If one litre of water was decomposed into hydrogen and oxygen gases, what pressure would be necessary to reduce the gases back to the original volume, one litre?
12. Explain the difference observed on throwing  $\text{K}$  and  $\text{Na}$  on cold water.
13. Write the reaction when  $\text{CaCO}_3$  is heated with  $\text{NH}_4\text{Cl}$ . How would you prove the reaction?
14. How would you test impure  $\text{Na}_2\text{SO}_4$  for borax?
15. Give three ways for obtaining crystals, and examples of each.
16. Write the reaction when  $\text{KClO}_3$  is heated with chlorhydric acid.
17. Give the reactions for making  $\text{Na}_2\text{CO}_3$  by the "ammonia process." Leave no waste products.
18. How could you prove a substance to be  $\text{SiO}_2$ ? Give reactions.
19. From  $\text{Na}_2\text{SO}_4$  make  $\text{Na}_2\text{S}$ . From  $\text{Na}_2\text{S}$  make  $\text{Na}_2\text{SO}_4$ .

#### April, 1888.

1. What is a "double salt"? Illustrate by examples.
2. When anhydrous calcium chloride dissolves in water, heat is evolved. When the hydrated salt dissolves in water, heat is absorbed. What bearing does this have on the idea that salts in solution retain their "water of crystallization"?
3. How change ferrous to ferric sulphate?
4. When  $\text{FeO}$  is fused with  $\text{KNO}_3$  and  $\text{Na}_2\text{CO}_3$ , some ferrate of potassium ( $\text{K}_2\text{FeO}_4$ ) is formed. Write the reaction, supposing  $\text{NO}$  gas to be evolved. Explain the use of  $\text{KNO}_3$  and  $\text{Na}_2\text{CO}_3$ .

5. When  $\text{SrN}_2\text{O}_6$ ,  $\text{KClO}_3$ , and S are heated together, what takes place? Show by reactions what the final products will be.

6. Which of the following gases can be easily collected over water:  $\text{HCl}$ ,  $\text{NH}_3$ ,  $\text{NO}_2$ ,  $\text{NO}$ ,  $\text{N}_2\text{O}$ ,  $\text{HI}$ ,  $\text{HF}$ ,  $\text{O}$ ,  $\text{Cl}$ ,  $\text{CO}_2$ ,  $\text{CO}$ ?

7. How would you separate  $\text{CO}_2$  from  $\text{CO}$  gas?

8. How would you make aluminum acetate? Acetic acid is  $\text{HC}_2\text{H}_3\text{O}_2$ . Equations.

9. Given iron, aluminum, chromium, and manganese alum. How would you distinguish between them?

10. What is a "double salt"? What examples have you had?

11. How much zinc would be required to precipitate the silver and copper from a solution made by dissolving in nitric acid 250 grms. of an alloy of 90 per cent silver and 10 per cent copper?

12. When  $\text{CO}_2$  gas is passed into lime water, what do you notice? Explain.

13. What is an "alum"? A "lake"? A "mordant"?

14. How change  $\text{MnO}_2$  to permanganic acid?

15. State the "law of multiple proportions." Illustrate by examples.

16. Which of the following are soluble in water:  $\text{Pb}(\text{C}_2\text{H}_3\text{O}_2)_2$ ,  $\text{NaCl}$ ,  $\text{AgCl}$ ,  $\text{BaSO}_4$ ,  $\text{Na}_2\text{CO}_3$ ,  $\text{CaCO}_3$ ,  $\text{K}_2\text{SO}_4$ , oxalic acid,  $\text{K}_2\text{Mn}_2\text{O}_8$ ,  $\text{Cr}_2\text{O}_3$ ,  $\text{CrO}_3$ ? If not soluble in water, are they in chlorhydric acid?

17. From 5 grms. of a substance there was obtained 1 cc. of N gas measured at  $20^\circ\text{C}$ . and 765 mm. pressure. Calculate what per cent of N there was in the substance. ( $N = 14$ .)

18. Define a "basic"; an "acid"; a "neutral" salt. Which are the following:  $\text{CuSO}_4$ ,  $\text{Na}_3\text{AlO}_6$ ,  $\text{NaHSO}_4$ ?

19. Give relative solubilities of  $\text{Na}_2\text{SO}_4$ ,  $\text{BaSO}_4$ ,  $\text{SrSO}_4$ , and  $\text{CaSO}_4$ .

20. Write the reaction of  $\text{H}_2\text{SO}_4$  and  $\text{HNO}_3$  on Cu.

21. Reaction of  
 $\text{H}_2\text{S}$  on  $\text{HNO}_3$ ;  
 $\text{HCl}$  on  $\text{KClO}_3$ ;  
 $\text{SO}_2$  on  $\text{PbO}_2$ ;  
 $\text{SO}_2$  on  $\text{NaOH}$ ;  
 $\text{Cl}_2$  on  $\text{KOH}$ ;  
 $\text{HNO}_3$  on  $\text{KI}$ .



22. Give a test for a carbonate, sulphite, sulphide, nitrate, sulphate, chloride, chlorate, bromide, and iodide.

23. To a solution of  $\text{ZnSO}_4$ ,  $\text{NaOH}$  is added in excess. Write the reaction.

24. How separate an alloy of  $\text{Cu}$  and  $\text{Ag}$  and obtain the metals in a pure state?

25. What are the principal sources of the potassium compounds? Give two methods of preparing  $\text{K}_2\text{CO}_3$ .

26. When litharge and sodium carbonate are fused on charcoal with the reducing flame, what happens? Explain fully the use of the reducing flame and of the sodium carbonate.

27. Give two methods of softening "hard" waters.

28. Give the reaction for preparing  $\text{N}_2\text{O}$ ,  $\text{NO}$ ,  $\text{CO}$ ,  $\text{NH}_3$ ,  $\text{HCl}$ ,  $\text{O}_2$ ,  $\text{Cl}_2$ .

29. Reactions for preparing acetate of aluminum, sulphate of barium, chromate of lead, sulphide of zinc, chloride of gold.

30. Given 10 grms. of silver dissolved in nitric acid. How much  $\text{HCl}$  solution (sp. gr. = 1.2) and containing 33 per cent of  $\text{HCl}$  will be required to precipitate all the silver as silver chloride?

## METRIC SYSTEM TABLES.

## MEASURES OF LENGTH.

*Standard Unit — One Metre.*

|              |                |              |             |
|--------------|----------------|--------------|-------------|
| 1 Kilometre  | = 1000 Metres. | 1 Metre      | = 1. Metre. |
| 1 Hectometre | = 100 "        | 1 Decimetre  | = 0.1 "     |
| 1 Decameter  | = 10 "         | 1 Centimetre | = 0.01 "    |
| 1 Metre      | = 1 Metre.     | 1 Millimeter | = 0.001 "   |

|              |                        |
|--------------|------------------------|
| 1 Kilometre  | = 0.6214 Mile.         |
| 1 Metre      | = 3.2809 Feet.         |
| 1 Centimetre | = 0.3937 Inches.       |
| 1 Inch       | = 2.53995 Centimetres. |

## MEASURES OF VOLUME.

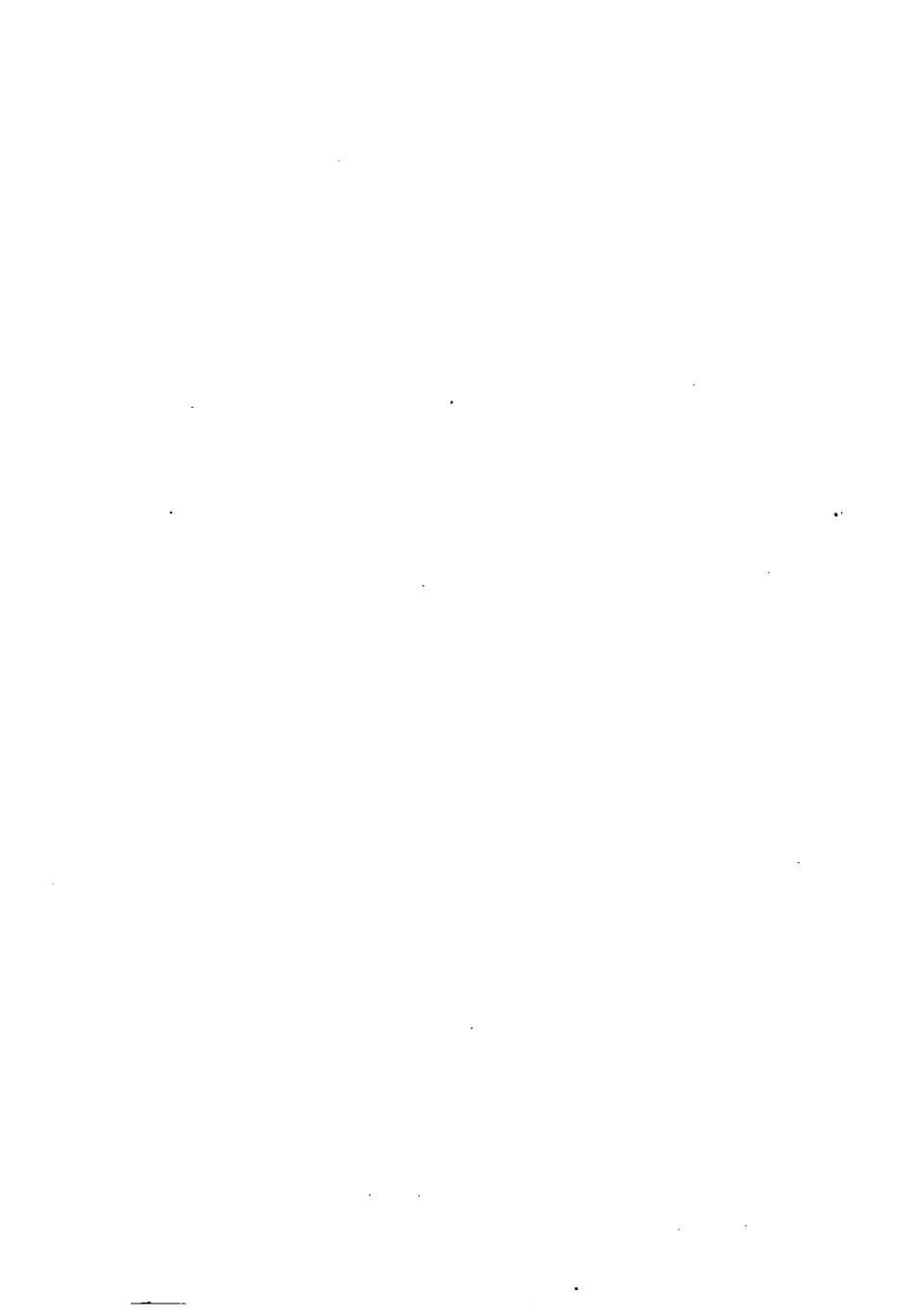
|                    |                          |
|--------------------|--------------------------|
| 1 Cubic Metre      | = 1000 Litres.           |
| 1 Cubic Decimetre  | = 1 Litre.               |
| 1 Cubic Centimetre | = 0.001 "                |
| 1 Litre            | = 61.02705 Cubic Inches. |
| 1 Litre            | = 1.05672 U. S. Quarts.  |

## MEASURES OF WEIGHT.

*Standard Unit — One Gramme.*

|               |                 |               |               |
|---------------|-----------------|---------------|---------------|
| 1 Kilogramme  | = 1000 Grammes. | 1 Decigramme  | = 0.1 Gramme. |
| 1 Hectogramme | = 100 "         | 1 Centigramme | = 0.01 "      |
| 1 Decagramme  | = 10 "          | 1 Milligramme | = 0.001 "     |

|                  |                             |
|------------------|-----------------------------|
| 1 Kilogramme     | = 2.204621 Pounds (Avoir.). |
| 1 Kilogramme     | = 32.15073 Ounces (Troy).   |
| 1 Gramme         | = 15.43235 Grains.          |
| 1 Grain          | = 64.799 Milligrammes.      |
| 1 Pound (Avoir.) | = 7000 Grains.              |
| 1 Litre water    | = 1000 Grammes.             |



## *The English Language; Its Grammar, His-*

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